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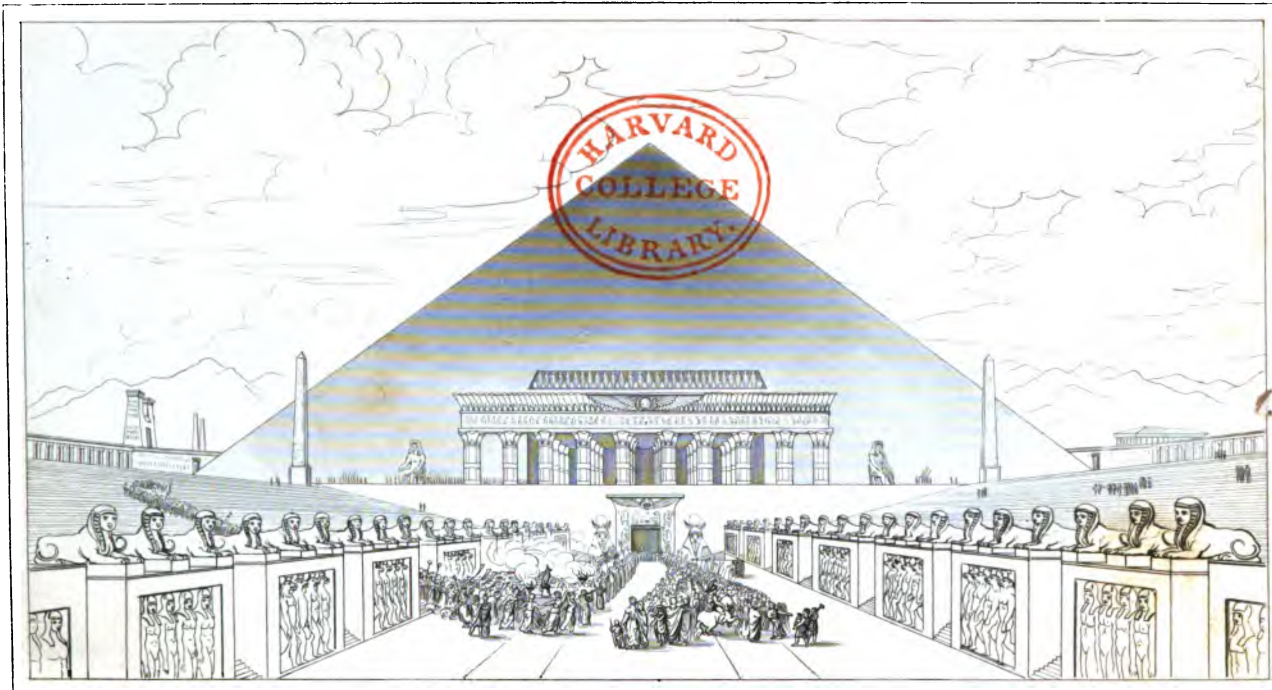
RESTORATION OF AN EGYPTIAN PYRAMID: See page 24



RESTORATION OF AN EGYPTIAN PYRAMID.

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THE

USEFUL ARTS,

CONSIDERED IN CONNEXION

WITH THE

APPLICATIONS OF SCIENCE:

WITH NUMEROUS ENGRAVINGS.

BY JACOB BIGELOW, M.D.

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IN TWO VOLUMES.

VOL. I.

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ADVERTISEMENT.

The following volumes are furnished for publication, at the request of the Publishers of the School Library, now issuing under the sanction of the Massachusetts Board of Education. Most of their subjects were formerly comprised in a course of lectures, delivered in Harvard University, and afterwards published, in two editions of the author's 'Elements of Technology.' The Work is now prepared for the press, with various modifications and additions, intended, chiefly, to bring the account of its subjects down to the present time. An historical chapter is also prefixed to the Work, and several new subjects introduced in its pages.

The degree of interest, which was formerly taken in the Lectures alluded to, led the author to believe, that the subject is, in itself, peculiarly capable of exciting the attention and curiosity of students. There can be no doubt, that the knowledge, which this study is intended to furnish, is of great use in the common affairs of life; and, probably, its advancement has contributed, more than that of any other science, to the improved condition of the present age.

A certain degree of acquaintance with the theory and scientific principles of the common arts is found so generally important, that most educated men, in the course of an ordinary practical life, are obliged to obtain it from some source, or to suffer inconvenience, for the want of it. He who builds a house, or buys an estate, if he would avoid disappointment and loss, must know something of the arts, which render them appropriate and tenantable. He who travels abroad, to instruct himself, or enlighten his countrymen, finds, in the works of art, the most commanding objects of his attention and interest. He who remains at home, and limits his ambition to the more humble object of keeping his apartment warm, and himself comfortable, can only succeed, through the instrumentality of the arts.

There has, probably, never been an age, in which the practical applications of science have employed so large a portion of the talent and enterprise of the community, as in the present; nor one, in which their cultivation has yielded such abundant rewards. And it is not the least of the distinctions of our own country, to have contributed to the advancement of this branch of improvement, by many splendid instances of inventive genius, and successful perseverance.

The importance of the subject, and the prevailing interest which exists, in regard to the arts and their practical influences, appear, commonly, to have created a want, not provided for, in our courses of elementary education. In-

formation on these subjects is scattered through the larger works on mechanics, on chemistry, mineralogy, engineering, architecture, domestic economy, the fine arts, &c.; so that it rarely happens, that a student, in any of our colleges, gathers information enough to understand the common technical terms, which he meets with, in a modern book of travels, or periodical work. It is only by making the elements of the arts themselves, subjects of direct attention, that this deficiency is likely to be supplied.

In the present volumes, it is attempted to include such an account, as the limits may permit, of the principles, processes, and nomenclatures, of the more conspicuous arts; particularly those, which involve applications of science, and which may be considered useful, by promoting the benefit of society, together with the emolument of those who pursue them.

In preparing for the press the lectures, on which this Work was founded, some variations from the original form were made, together with such additions, as leisure from professional engagements permitted. In doing this, occasional use was made of the works of Robison, Young, Tredgold, and several of the late chemical writers. But, as these elementary volumes are composed for the instruction of the uninitiated, rather than for the perfection of adepts, it has been found necessary to condense, and to endeavor to render intelligible, the subjects of consideration, rather than to dilate them, by minute expositions and details. For the use of those students, who may

wish to extend their inquiries, in reference to any of the particular subjects, a list of some of the more prominent authors, and works of value, that treat upon the several subjects, is subjoined, at the end of each chapter. Among some of these works, the authorities for the facts stated in the preceding chapter, will, in most instances, be found.

An Appendix is added to the second volume, consisting of miscellaneous accounts, relating to certain subjects of interest. In each volume, a Glossary, for the use of students, and copious Indexes, complete the Work.

J. B.

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INTRODUCTION.

It is difficult to draw a strict line of division between the *sciences*, as they are usually called, and the *arts*, since in many branches of human knowledge, the two are so blended together, that it is impossible to make their separation complete. In common language, we apply the name of *sciences* to those departments of knowledge which are more speculative, or abstract, in their nature, and which are conversant with truths or with phenomena, that are in existence at the time we contemplate them. The *arts*, on the contrary, are considered as departments of knowledge, which have their origin in human ingenuity, which depend on the active, or formative processes of the human mind, and which, without these, would not have existed. Our knowledge may be said to have been found out originally by discovery and invention. Discovery is the process of science ; invention is the work of art. So common, however, is the connexion of the two with each other, that we find both a science and an art involved in the same branch of study. For example, chemistry is a science depending on the immutable relations of matter, which relations must have existed, had there never been minds to study them. Yet these laws of matter would not have become the subjects of science, had not mankind invented the *art* of separating their agents, and making them cognizable to the senses. To

build a ship, to construct a watch, or paint a picture, are all operations of art; yet they all have their foundation in a certain acquaintance with mathematical rules, and principles of natural philosophy. Those artists, who work with thorough knowledge of principles, we are accustomed to denominate scientific; while those, who experiment at random, or who blindly copy the results of others, we consider empirical. Thus it appears that an intimate connexion and dependence exists between sciences and arts, and it follows that the claim which they offer to our attention is in a great measure of the same kind. Of the latter, as well as the former, we already require some, as branches of a common education; while of the rest there are few which may not be advantageously studied, either as affording exercise for talents, discipline for taste, or practical advantage in the common concerns of life.

The connexion of the arts with the sciences is more common and obvious in modern times, than it was in the days of antiquity. During the process of civilization, or the whole period which elapses between barbarism and complete refinement, the arts have uniformly taken precedence both of science and literature. Rude nations commence the improvement of their state, by an attention to agriculture, to building, to navigation, and to sculpture. The want of an acquaintance with the real or scientific principles of these arts, obliges them to substitute the effects of manual labor and dexterity, for scientific method; and hence the paths in which they excel, have been usually of a different character from those of people whose knowledge and resources are greater. The ancients, who were but recently descended from barbarians, were obliged to make the most of small

means, because the stock of previous or common information, from which they could draw, was extremely limited. The moderns have the accumulated learning of ages before them, and have only to select and apply their agents from among a multitude of means already discovered. The qualities, by which the former arrived at excellence, were more or less concentrated in individuals; while with us the means of excellence are recorded in books, and are at the disposal of communities. They possessed the quick eye, the expert hand, acute taste, and unwearied industry. For these we substitute preparatory science, economical computation, and mechanical power. Their processes differ from ours, as the process of the savage, who fashions and polishes his war-club by the truth of his eye, and the patience and dexterity of his hand, differs from that of the civilized mechanic, who turns the same kind of thing, in a hundredth part of the time, in a lathe, which another man has invented for him. The ancients were prodigal of means, and lavished men and treasures when any great work was to be accomplished. The moderns save expense, and labor, and time, in every thing. The economy of the ancients consisted in diminishing their personal wants; ours, in devising cheap means to gratify them. They prepared their soldiers for war by inuring them to hunger and fatigue; we, by keeping them well fed and clothed. Their stateliest edifices were destitute of chimneys and glass windows, yet, when left to themselves, they have stood for thousands of years. Ours abound in the means of making their present tenants comfortable, but are often built too cheaply to be durable. They conveyed water to their cities in immense horizontal channels, supported on arcades of prodigious elevation. We convey it over

hills and under valleys in hydraulic pipes of the most trivial size. Wherever art could precede philosophy, the ancients have exhibited the grandest productions of genius and strength; but, in the application of philosophy to the arts, the moderns have achieved what neither genius nor strength, unassisted, could have performed. The imitative arts, and those which require only boldness and beauty of design, or perseverance in execution, were carried in antiquity to the most signal perfection. Their sculpture has been the admiration of subsequent ages, and their architecture has furnished models which we now strive to imitate, but do not pretend to excel. We might, if this were the place, add their poetry, and their oratory, to the list of arts which flourished in perfection during the youthfulness of intellectual cultivation. But in modern times, there is a maturity, a cautiousness, a habit of induction, which is founded on the advanced state of philosophic knowledge. Our arts have been the arts of science, built up from an acquaintance with principles, and with the relations of cause and effect. With less bodily strength, and probably with not more vigorous intellects, we have acquired a dominion over the physical and moral world, which nothing but the aid of philosophy could have enabled us to establish. We convert naturel agents into ministers of our pleasure and power, and supply our deficiencies of personal force by the application of acquired knowledge. Among us, to be secure, it is not necessary that a man should be powerful and alert; for even where laws fail, the weak take rank with the strong, because the weakest man may arm himself with the most formidable means of defence. The labor of a hundred artificers is now performed by the operations of a single machine. We traverse the ocean in security, because

the arts have furnished us a more unfailing guide than the stars. We accomplish what the ancients only dreamed of in their fables; we ascend above the clouds, and penetrate into the abysses of the ocean.

The application of philosophy to the arts is a more fruitful theme, than can well be condensed into a limited work, or course of instruction. While it comprises some of the sources even of ancient refinement, it includes a great part of the grounds of modern superiority. The application of philosophy to the arts may be said to have made the world what it is at the present day. It has not only affected the physical, but has changed the moral and political condition of society. The invention of the printing-press dispersed the darkness of the middle ages, and carried truth and knowledge to every portion of the world. The artificial combination of sulphur, nitre, and charcoal, has revolutionized the customs and the arts of war, and, even in military life, has given the mind the advantage over the body. The moderns have imparted magnetism to a piece of steel, and suspended it on a pivot; and what has been the consequence? It has opened to them a path across unknown seas, and has disclosed a new continent to the inhabitants of the old, a successor to their arts and their power. It has developed the wealth of unknown islands, has brought the remotest countries together, and has made the ocean the resort and support of multitudes. Let any one, who would know what modern arts have accomplished, compare the repeating watch, and the unerring chronometer of the present day, with the rude sun-dial and clepsydra of the ancients. Let him consider the multiplied advantages which attend the manufacture of glass, which has enabled us to combine light with warmth in our houses;

which has given sight to the aged, which has opened the heavens to the astronomer, and the wonders of microscopic life to the naturalist. Let him attend to the complicated engines and machinery, which are now introduced into almost every manufacturing process, and which render the physical laws of inert matter a substitute for human strength.

But it is not the contrast with antiquity alone, that enables us to appreciate the benefits which modern arts confer. In the present inventive age, even short periods of time bring with them momentous changes. Every generation takes up the march of improvement where its predecessors had stopped, and every generation leaves to its successors an increased circle of advantages and acquisitions. Within the memory of many who are now upon the stage, new arts have sprung up, and practical inventions, with dependent sciences; bringing with them consequences which have diverted the industry, and changed the aspect of civilized countries. The augmented means of public comfort and of individual luxury, the expense abridged and the labor superseded, have been such, that we could not return to the state of knowledge which existed even sixty years ago, without suffering both intellectual and physical degradation. At that time, philosophy was far distant from its present mature state, and the arts which minister to national wealth were in comparative infancy. No man then knew the composition of the atmosphere, or of the ocean. The beautiful and intricate machinery, which weaves the fabric of our clothing, was not even in existence. When George III. visited the works of Messrs. Boulton and Watt, at Birmingham, and was told that they were manufacturing an article of which kings were fond, and that that article was power; he was struck with

the force and disadvantageousness of the comparison. Yet the steam-engine had not then been launched upon the ocean, and had developed only half its energies.

So long as the arts continue to exert the influence, and to yield the rewards, which they have hitherto done, there will be no want of competent minds and hands, to carry forward their advancement. With their increasing consequence, there must also be an increasing attention to their study and dissemination. Curiosity keeps pace with the interest and magnitude of its objects. And unless the character of the present age is greatly mistaken, the time may be anticipated as near, when a knowledge of the elements and language of the arts will be as essentially requisite to a good education, as the existence of the same arts is to the present elevated condition of society.

THE USEFUL ARTS.

CHAPTER I.

HISTORICAL OUTLINE OF THE PROGRESS OF THE ARTS IN ANCIENT AND MODERN TIMES.

ARTS OF THE EGYPTIANS.—Architecture, Pyramids, Sphinx, Labyrinth, Obelisks, Cities, Tombs, Sculpture, Houses, Mills, Transporting of Weights, Glass, Linen, Cotton, Woollen, Writing Materials, Leather, Trades, Furniture, Boats, Dress, Metals and Minerals, Gold-mines. ARTS OF THE ASSYRIANS. ARTS OF THE HINDOOS. ARTS OF THE PERSIANS. ARTS OF THE HEBREWS. ARTS OF THE GRECIANS.—Architecture, Sculpture, Painting. ARTS OF THE ROMANS.—Nero's House, Amphitheatre, Temples, Arches, Columns, Aqueducts, Roads, Bridges, Houses, Riding, Statuary, Painting, Implements, Domestic Arts, Herculaneum, Pompeii. ARTS OF THE CHINESE. ARTS OF THE ARABIANS. ARTS OF THE MIDDLE AGES.—Gunpowder, Mariner's Compass, Clocks, Optical Instruments. ARTS OF MODERN TIMES.—Printing, Chimneys, Glass Windows, Carriages, Pavements, Oil Painting, Engraving, Optical Instruments, Watches, Paper, Cotton Spinning, Prints, Hat-making, Metals, Aerostation, Diving-bell, Steam-engine. ARTS OF THE NINETEENTH CENTURY.—Steam-boats, Railroads, Gas-lights, Argand Lamps, Stereotyping, Machine Printing, Lithography, Steel Engraving, McAdam Roads, Wooden Pavements, India rubber, Labor-saving Machinery.

IT is impossible, at the present day, to trace with any certainty the steps which were first made by mankind in the various practical inventions that have tended to ameliorate the condition of their race. Many important arts undoubtedly preceded the use of written characters, and therefore no authentic records were made of their origin and early progress. In countries where some degree of civilization is known to have existed at a remote period, there are found at the present time relics of works which excite our wonder by their magnitude and the diffi-

culty of their execution, but respecting which, the earliest historians furnish only traditionary or fabulous accounts. On some of these a new light has been thrown in late years by the interpretation of hieroglyphic inscriptions, which enable us to assign to many elaborate and difficult arts a degree of antiquity, which without such authority would have surpassed belief. Mankind in all ages have felt the same necessities, and, as their civilization has advanced, have sooner or later imbibed a taste for the same conveniences and gratifications. Hence different nations appear to have arrived at a knowledge of the same arts by a common process, either of experiment and induction, or of imitation of what had been done by others. The different periods in which they have converted to practical use the means and materials around them, have depended upon the aptitude of different races for improvement, the judicious administration of their respective governments, and their exemption from frequent and overwhelming calamities.

ARTS OF THE EGYPTIANS.

All nations are agreed in looking back to ancient Egypt as the common, if not the original parent of most of the useful arts, as well as of science and letters. Herodotus, the Greek historian, who visited Egypt more than four hundred years before the Christian era, found the pyramids not only then standing, but considered at that time as antiquities of remote origin. Besides these, there were in existence in his time many stupendous edifices, subterranean structures, colossal statues, and elaborate works of sculpture. The same things now exist in some instances almost unimpaired, and excite the wonder of travellers at the present day. The French savans, who accompanied the military expedition to Egypt under Bonaparte, have published minute and extensive representations of the antiquities of that country. The traveller Belzoni and his contemporaries, by their researches and excavations, have brought to light many facts and circumstances of the highest interest. More recently, Mr. Wilkinson has placed before the public a vast amount of information, relating to the customs, arts, and manufactures of the ancient Egyptians, derived

from inscriptions and paintings now extant upon the walls of their buildings, and from various pieces of workmanship, which are found remaining in good preservation. But unquestionably the most interesting discovery connected with this subject, is that of M. Champollion, who, by deciphering the hieroglyphic inscriptions, has been enabled to give us names, dates, and historical facts, which seem to show, that many of the most astonishing structures and works of art of the Egyptians were in existence a thousand years before the time of Herodotus.

Architecture.—The power which was acquired by the ancient inhabitants of Egypt, of removing and erecting large masses of stone, together with their taste for the pyramidal form, the most stable of all modes of construction, has been the cause that so many memorials of their attainments in art have descended to the present day. Many of the other structures of antiquity now extant owe their preservation to accident; those of Egypt have the principle of their preservation within themselves.

Pyramids.—The Egyptian pyramids surpass all other works of art in the interest excited by their antiquity and immense size, and by the contemplation of the vast and concentrated power, which was called into exercise for their erection. These structures appear to have been reared either as the sepulchres of the monarchs who designed them, or else as the tombs of some deified objects of veneration among the inhabitants. The number of pyramids which are found in Egypt and the neighboring countries, including Nubia, exceeds a hundred, and some of them are unquestionably the largest edifices on the globe. The most remarkable and best known, are those at Ghizeh, near Cairo. Of these the largest is seven hundred and sixty-three feet square, according to the admeasurements of M. Jomard, who went to the trouble of removing the earth down to the base of this pyramid, to obtain its true dimensions. The whole area, or space covered by this structure, exceeds thirteen English acres. The total height is about four hundred and seventy-nine feet, being somewhat higher than St. Peter's church at Rome. The outside presents a succession of courses of

vast stones rising like stairs one above another, decreasing in size from below upwards, so that the lowest stones measure about four feet and a half in height, and the uppermost one foot and a half. The summit is a platform thirty-two feet square, composed of nine stones.

It is supposed that some of the pyramids were covered with a casing of smooth stones with an oblique outer side, which filled up the steps, or notches, and gave to the whole outside a plane surface. None of these casing-stones are found at this day on the larger pyramid, but in the second pyramid they exist on some of the upper steps, and in the third they are found from top to bottom. Some of the Nubian pyramids have large propylæa, or porticoes, still standing, and the vestiges of a temple are to be seen before one of the pyramids of Ghizeh. From the well-known magnificence of the Egyptian style of building, it seems probable that these pyramids were the nuclei, or bodies, of ornamental groups and ranges of structures. The frontispiece represents one of the largest pyramids, as restored, by the French antiquarian Casas, to its supposed original state, with its porticoes and obelisks, and its avenues of sphinxes and statues. The group combines a good view of the peculiarities of Egyptian architecture.

The outside of the principal Egyptian pyramids is of hewn stone; the inside is a solid mass of rubble. The largest of these structures has an entrance on the north side, about forty-seven feet above the base. From this entrance a passage, or narrow gallery, extends into the body of the pyramid, in a sloping direction downward. This terminates in another passage which slopes upward, and which is succeeded in its turn by a horizontal passage leading to a small chamber in the centre of the building. Another passage, partly sloping and partly horizontal, leads to a different chamber situated higher than the former, and containing a granite sarcophagus at one end. The contents of this sarcophagus, and also its lid, have long since disappeared. The walls of the passages and chambers are lined with polished granite, some of the stones being seventeen and even twenty feet in length.

An opening was made into the second pyramid by the traveller Belzoni, by penetrating the wall in a part corresponding to the entrance of the first. He discovered a long gallery, partly sloping and partly horizontal, which terminated, as in the first instance, in a central chamber containing a stone sarcophagus. In this sarcophagus were still remaining the bones of its occupant. These, on being duly examined, were found to be the bones, not of an Egyptian monarch, but of a common bull! So that it appears possible that these vast and cumbrous edifices were erected to serve, not as the tombs of kings, but as the monuments of mere brutes, to the worship of which the Egyptians are well known to have been addicted.

Sphinx.—In front of the pyramids of Ghizeh, and about a quarter of a mile from the banks of the Nile, is another extraordinary production of the ancient Egyptians, the immense figure called the Sphinx of Ghizeh. It is of the kind called androsphinx, the face of which is that of a man, and the body that of a lion. This wonderful work of art is said to have been the sepulchre of the King Amasis. It is of one entire stone, and appears to have been cut out of a solid rock. Till the time of the French invasion of Egypt, little was to be seen of this celebrated figure, except the head, the rest having been buried for ages in sand. This obstacle they cleared away in a considerable degree, and laid much of the body open to view. From recent measurements, calculated when the Sphinx was cleared from the sand, it is found to be about a hundred feet in length and forty feet wide. Dr. Pococke, and M. Goguet, after him, reckoned the head to be twenty-six feet high, thirty-five feet round, and fifteen feet from the ear to the chin.

The public are indebted for farther light to Captain Cabillia, who succeeded with great labor in uncovering the front of the Sphinx. He found a small temple situated between the two paws, and a large tablet of granite on its breast. The tablet is adorned with several figures and hieroglyphics, and two representations of other sphinxes are sculptured upon it. Before the entrance into the small temple was a lion, placed as if to guard the approach.

From the base of the temple to the summit of the head he found to be sixty-five feet; the legs of the Sphinx are fifty-seven feet long from the breast to the extremity of the paws, which are eight feet high. He also found a Greek inscription of the time of the Ptolemies, one alluding to the Emperor Antoninus, and another to Septimius Severus.

Sphinxes of smaller size, having the head of a woman, are common in Upper Egypt, and, in some instances, rows of these figures appear to have lined the sides of avenues a mile or more in length. The idea of the Sphinx was not peculiar to Egypt. They are found at Persepolis, and at Ellora in India.

Labyrinth.—Next in point of celebrity, is the Egyptian Labyrinth, which the Greeks imitated in the well-known Labyrinth of Crete. It has been doubted if any remains of this elaborate structure have been discovered, yet Captain Wilford asserts, that its ruins are still to be seen near the Lake Mœris. We must, however, rely upon the credit of ancient authors for our knowledge respecting it, and the account of Herodotus, though perhaps exaggerated, is the best to which we can refer upon this head. There is great diversity of opinion in regard to the period to which the construction of this edifice ought to be attributed.

The Labyrinth, as Herodotus affirms, contained within the same circuit of walls twelve magnificent palaces, regularly disposed and communicating with each other. These palaces contained three thousand halls, twelve of which were of a particular form and great beauty. Half of these halls, or chambers, were interspersed with terraces, and communicated with each other, but by so many turns and windings, that, without an experienced guide, it was impossible to escape out of them. The other half were under ground, cut out of the rock, and said to be used for the sepulchres of Egyptian kings. Herodotus states, that he visited all the apartments above ground; but those which were subterraneous, they would not, from motives of superstition, permit him to enter. Captain Wilford thinks the various apartments under ground were used for depositing the chests or coffins of the sacred crocodiles,

called sukhus, or sukkis, in old Egyptian, and soukk, to this day, in the vernacular language of Egypt. The halls had an equal number of doors, six opening to the north and six to the south, and at each angle of the external wall of the Labyrinth was erected an immense pyramid, for the sepulchres of its founders. The whole building of the Labyrinth, walls and ceilings, was of white marble, and exhibited a profusion of sculpture. Each of the twelve halls or galleries before mentioned was supported on columns of the same marble. This building, or rather city of palaces, is also mentioned by Diodorus Siculus, who thinks it was a grand cemetery for the Egyptian monarchs and their families; and by Strabo and by Pliny, who only confirm the descriptions of Herodotus.

Obelisks.—Obelisks were slender pyramidal shafts made of a single stone, and generally placed in pairs before gates or propylæa of temples or cities. They have generally been considered as peculiarly Egyptian, and of Egyptian origin, yet, if the account of Diodorus be true, it must have been in Asia, and not in Egypt, that they took their rise. This author speaks of a pyramidal spire, erected by the command of Semiramis on the road to Babylon, which was of a single stone, one hundred and thirty feet in height, and twenty-five feet square at base. Pliny, on the contrary, asserts, that the idea of this species of monument was originally conceived by the Egyptians, and that a king of Heliopolis, called Mestres, was the first who caused an obelisk to be raised.

Two of the principal of these obelisks were those which were supposed to have been erected by Sesostris or Rameses, with the design of communicating to posterity the extent of his power, and the number of the nations he had conquered. These obelisks were each of one immense piece of granite, and were a hundred and eighty feet high. Augustus, according to the report of Pliny, transported one of these obelisks to Rome, and placed it in the Campus Martius. Of the three Egyptian obelisks now in Rome, doubts have been suggested whether either of them was raised by Sesostris, on account of their smaller

height. The height of that now by the fountain of the Piazza del Popolo is seventy-four feet, without its modern pedestal; that of the Vatican, seventy-eight feet, and that on Trinita, forty-five feet, without their pedestals, while those of Sesostris were said to be of the enormous altitude of one hundred and eighty. If the two larger be the same, it is probable they were broken shorter in their fall. The obelisk of the Piazza del Popolo is that which was brought to Rome by Augustus, after being spared from the ravages of Cambyses. From the place where it was erected by Augustus, this obelisk was removed to its present situation by order of Sextus the Fifth, in 1589, under the direction of Fontana, who also designed its pedestal and the fountain. The one now in front of St. Peter's church is also said to be one of those erected at Heliopolis, by Sesostris, and was brought to Rome by Caligula in a vessel, the largest then ever seen upon the sea, and which was afterwards sunk to form the port of Ostia. That Emperor erected it in his circus at the Vatican, which was destroyed by Constantine the Great, to build the first basilica of St. Peter's; but he left the obelisk standing in the place now occupied by the Sacristy of St. Peter. It was removed, at an expense of nearly £10,000 sterling, by Sextus, to its present situation, nearly a century before the construction of the colonnade which surrounds it.

Cities.—At various places in Upper Egypt, upon the banks of the Nile, the remains of ancient cities are met with, the elaborate works of which are objects of astonishment to modern visiters. Some of the most remarkable of these are found on the sites of the ancient Hermopolis and Tentyra. But at the villages now called Carnac and Luxor, remain the ruins of ancient Thebes, constituting the most interesting and stupendous collection of works of high antiquity, which are to be found in any part of the world.

We are told that at the period of the Trojan war, Thebes was considered the most opulent, and the best peopled city in existence. It was distinguished by the epithet Hecatompylos, from its hundred gates. It was

not only the most beautiful city in all Egypt, but is supposed by many ancient writers to have surpassed every other of its time, in the splendor of its buildings, in its extent, and in the number of its inhabitants. Homer says, that Thebes was able to furnish 20,000 chariots of war. Its four principal temples were of immense size, and of singular beauty of workmanship. The gold, ivory, and precious stones, with which they were decorated, were stripped and carried away by the Persians, when Cambyses conquered and ravaged Egypt. Their domestic architecture appears to have arrived at a high degree of perfection. Diodorus says, the houses of private persons in Thebes were four and five stories in height, which proves the knowledge of floors, stairs, and other necessary mechanism of storied dwellings.

The following account of the present aspect of the ruins of this remarkable city is derived from the work of a recent and highly-intelligent American traveller, Mr. Stephens.

"At this day the temples of Thebes are known almost every where, by the reports of travellers. On the Arabian side of the Nile, are the great temples of Luxor and Carnac. The temple of Luxor stands near the bank of the river, built there, as is supposed, for the convenience of the Egyptian boatmen. Before the magnificent gateway of this temple, until within a few years, stood two lofty obelisks, each a single block of red granite, (or sienite,) more than eighty feet high, covered with sculpture and hieroglyphics, fresh as if but yesterday from the hands of the sculptor. One of them has been lately taken down by the French, and is now in Paris; the other is still standing on the spot where it was first erected.

"Between these and the grand propylon are two colossal statues, with mitred head-dresses; also single blocks of granite, buried to the chest by sand, but still rising more than twenty feet above the ground. The grand propylon is a magnificent gateway, more than two hundred feet in length at its present base, and more than sixty feet above the sand. The whole front is covered with sculpture; the battle scenes of an Egyptian warrior,

designed and executed with extraordinary force and spirit. In one compartment the hero is represented advancing at the head of his forces, and breaking through the ranks of the enemy; then standing, a colossal figure, in a car drawn by two fiery horses with feathers waving over their heads, the reins tied round his body, his bow bent, the arrow drawn to its head, and the dead and wounded lying under the wheels of his car and the hoofs of his horses. In another place, several cars are seen in full speed for the walls of a town, fugitives passing a river, horses, chariots, and men struggling to reach the opposite bank, while the hero, hurried impetuously beyond the rank of his own followers, is standing alone, among the slain and wounded who have fallen under his formidable arm. At the farthest extremity, he is sitting on a throne as a conqueror, with a sceptre in his hand, a row of the principal captives before him, each with a rope around his neck; one with outstretched hands imploring pity, and another on his knees to receive the blow of the executioner, while above is the vanquished monarch, with his hands tied to a car, about to grace the triumph of the conqueror.

"Passing this magnificent entrance, the visiter enters the dromos, or large open court, surrounded by a ruined portico formed by a double row of columns covered with sculpture and hieroglyphics; and working his way over heaps of rubbish and Arab huts, among stately columns, twelve feet in diameter, and between thirty and forty feet in height, with spreading capitals resembling the budding lotus, some broken, some prostrate, some half buried, and some lofty and towering as when they were erected, at the distance of six hundred feet, reaches the sanctuary of the temple.

"But, great and magnificent as was the temple of Luxor, it served but as a portal to the greater Carnac. Standing nearly two miles from Luxor, the whole road to it was lined with rows of Sphinxes, each of a solid block of granite. At this end they are broken, and, for the most part, buried under the sand and heaps of rubbish. But approaching Carnac, they stand entire, still and solemn

as when the ancient Egyptian passed between them to worship in the great temple of Ammon. Four grand propylons terminate this avenue of sphinxes, and passing through the last, the scene which presents itself defies description. Belzoni remarks of the ruins of Thebes generally, that he felt as if he were in a city of giants; and no man can look upon the splendid ruins of Carnac, without feeling humbled by the greatness of a people who have passed away for ever.

"The field of ruins is about a mile in diameter; the temple itself twelve hundred feet long and four hundred and twenty broad. It has twelve principal entrances, each of which is approached through rows of sphinxes, as across the plain from Luxor, and each is composed of propylons, gateways, and other buildings, in themselves larger than most other temples; the sides of some of them are equal to the bases of most of the pyramids, and on each side of many are colossal statues, some sitting, others erect, from twenty to thirty feet in height. In front of the body of the temple is a large court, with an immense colonnade on each side, of thirty columns in length, and through the middle two rows of columns fifty feet in height; then an immense portico, the roof supported by one hundred and thirty-four columns, from twenty-six to thirty-four feet in circumference. Next were four beautiful obelisks more than seventy feet in height, three of which are still standing; and then the sanctuary, consisting of an apartment about twenty feet square, the walls and ceiling of large blocks of highly-polished granite, the ceiling studded with stars on a blue ground, and the walls covered with sculpture and hieroglyphics, representing offerings to Osiris.

"But these are not half the ruins of Thebes. On the western side of the river, besides others prostrate and nearly buried under the sands, the traces of which are still visible, the temples of Gornou, Northern Dair, Dair-el-Medinet, the Memnonium, and Medinet Abou, with their columns, and sculpture, and colossal figures, still raise their giant skeletons above the sands. Volumes have been written upon them, and volumes may

yet be written, and he that reads all will still have but an imperfect idea of the ruins of Thebes."

Tombs.—The ancient Egyptians, from the monarch to the subject, believed that their souls, after many thousand years, would come to reinhabit their bodies, in case these were preserved entire. Hence arose the embalming, and the situation of the sepulchres, in places not subject to the inundation of the river. The tombs at Thebes consist of sepulchral grottoes, made in the side of a hill, from its base to within three quarters of its summit. The lowest are the best executed, and the most spacious. The plan of all is nearly the same. A door open to the east leads to a gallery supported by columns or pilasters. At the end of the gallery is a well, which leads to the catacombs, where the mummies were deposited. These wells, from forty to sixty feet deep, abut upon long subterranean alleys terminating in a square room, supported by pillars, in which room are still remains of mummies. In the upper gallery are bas-reliefs or paintings on subjects relating to the funeral ceremonies; and every grotto had a ceiling painted in a fanciful manner, much resembling our paper for rooms. The tombs of the kings are particularly noticeable. The ancient road to them has not been found. Every grotto communicated with the valley by a large door. This leads into a succession of galleries, with chambers on both sides. One of these contains the actual sarcophagus, in which was placed the mummy of a king. It retains its cover, upon which is the royal effigy. The grand point of notice, however, in these souterrains is the fresco paintings. They exhibit all the arts of civilization which obtained in Egypt, such as relate to the manufactures and agriculture, saddlery, carriages, pottery, counters for trade, rural employment, hunting, fishing, marches of troops, punishments in use, musical instruments, habits, and furniture.

Sculpture.—The specimens which remain of Egyptian sculpture exceed those which are extant of any other nation, in their colossal size, and the labor which must have attended their execution. Before one of the gates

of Thebes, at the entrance of a temple long since destroyed, there now remain two gigantic statues of stone, both in a sitting posture, which measure from the ground fifty-three feet, besides a pedestal of seven feet now buried in the sand, making the total height sixty feet. One of these appears by inscriptions to have been the celebrated statue of Memnon, which was supposed by the ancients to emit a sound like that of a harp-string, at the rising of the sun. The fragments of another still more remarkable colossus are seen lying on the ground, broken but not destroyed. The breadth of this statue across the shoulders is twenty-two feet, and the arm from the shoulder to the elbow measures thirteen feet. Its foot is eleven feet in length and about five in breadth. The material of this statue is sienite, one of the hardest rocks, and its total weight is estimated at more than eight hundred tons.

Multitudes of statues of various dimensions, and their fragments, still appear among the ruins of Egyptian cities. They do not in general conform to the modern notions of beauty, being carved without much symmetry, the larger ones mostly in a sitting posture, with the limbs parallel, and the hands upon the knees. The Egyptian sculptors were in the habit of making both sides of these statues exactly alike in the attitude and position of the limbs. This peculiarity is incompatible with our ideas of grace or of life, and gives to their figures a stiff and inanimate appearance.

Some of their sculptures in relief represent erect figures in vigorous action, and these are considered as the most successful specimens of their art. Female figures have one arm crossed upon the breast. In the sculpture of animals they appear to have succeeded better than in that of men. Many of their works, both of painting and sculpture, represent fictitious objects having the heads of animals on the bodies of men, or other assemblages of heterogeneous features.

Houses.—Judging from the ruins that remain, the Egyptian towns appear to have been laid out with great regularity, the streets being, with the exception of a few principal ones, not wide enough to admit the passage of a

chariot. The houses were sometimes several stories high, and mostly made of crude bricks baked in the sun. The making of bricks was usually performed by the labor of captives, among whom the ancient Israelites were to be numbered. Various paintings remain which represent men engaged in every department of brick-making, with task-masters urging them on.

The houses of the wealthiest men frequently formed a hollow square, containing many apartments and enclosing a kind of court-yard. They had sometimes elaborate porticoes, with the name of the owner or occupant painted over the door. Rows of trees appear to have been cultivated in the streets and avenues. The rooms and other interior parts of the houses were plastered with stucco, and ornamented with various devices painted on the walls in fanciful and brilliant colors. The doors were often stained in imitation of ornamental wood, and had hinges of bronze, consisting of perpendicular pins entering into holes above and below. The floors were sometimes of stone or a composition of cement. The roofs were supported by rafters made of the date-tree, with transverse layers of palm branches or planks. Long stones were used in the more costly edifices, and the vault and arch appear to have been used in these constructions, as early as 1540 years before the Christian era.

Mills, &c.—The Egyptians had mills of a simple construction, consisting of two circular stones, of which the upper was turned on the under by means of a handle. They also had farms, orchards, and vineyards, made wine, and practised the ordinary arts of agriculture and gardening. All the important processes appertaining to these various operations are repeatedly depicted in paintings now extant on the ancient walls, and representations of them may be seen in the work of Mr. Wilkinson already alluded to.

Transporting of Weights.—The most ancient buildings in Egypt were constructed of limestone. It was occasionally employed for building even after the succession of the sixteenth dynasty, until the quarries of sandstone at Silsilis were opened.

When the stone was ready to be removed, it was transported on a sledge drawn by oxen, or if ponderous it was dragged by men condemned to hard labor. There exists, in a grotto of Egypt, a representation of a colossus which a large multitude of men are employed in dragging with ropes. It is one of the very few paintings which throw any light on the methods employed by the Egyptians for moving immense weights. One hundred and seventy-two men, in four rows of forty-three each, pull the ropes attached to the front of the sledge, and a liquid, probably grease, is poured from a vase, by a person standing on the pedestal of the statue, in order to facilitate its progress as it slides over the ground. Behind are four rows of men, who may be supposed to represent a new gang which relieved the others when fatigued. Below are persons carrying vases of the liquid, or perhaps water for the use of the workmen, and some implements, followed by taskmasters with their wands of office. On the knee of the figure stands a man who claps his hands apparently to the measured cadence of a song, to mark the time, and insure their simultaneous draught. The height of the statue appears to have been about twenty-four feet, and the color and the hieroglyphics inform us that it was of limestone. It was bound to the sledge by double ropes, which were tightened by means of long pegs inserted between them, and twisted round until completely braced; and to prevent injury from the friction of the ropes upon the stone, a compress of leather or other substance appears to be introduced at the part where they touched the statue.

Small blocks of stone were transported by water in boats or rafts. Those of large dimensions were dragged by men over land, and the immense weight of some of them shows that the Egyptians were well acquainted with the mechanical powers, and possessed the mode of applying a locomotive force with great success. The largest obelisk in Egypt, a single stone, has been computed to weigh two hundred and ninety-seven tons, and the distance from the quarry to where it now stands is one hundred and thirty-eight miles. Those taken to Heliopolis were

dragged over three hundred miles. Among the ruins of western Thebes, are two colossi which measure eleven thousand five hundred cubic feet, and are made of a stone not known within several days' journey of the place. Herodotus mentions a monolith at Sais, thirty-one and a half feet in length, twenty-two in breadth, and twelve in height, which two thousand men were employed to bring, and occupied three years in the task. His measurement is given as it lay on the ground—his length is therefore properly its height, and his height the depth from the front to the back.

The great knowledge of the mechanical powers, possessed by this people, is also shown in the erection of their obelisks, and in the position of vast stones raised to a considerable height, and adjusted with the utmost precision, sometimes in situations where the space will not admit the introduction of the inclined plane.

In one of the quarries at Syene, is a granite obelisk, which, having been broken in the centre after it was finished, was left in the exact spot where it was separated from the rock. The breadth of the quarry is so small, and the entrance to it so narrow, that it was impossible for the workmen to turn the stone in order to remove it by that opening; it is therefore evident that they must have lifted it out of the hollow in which it had been cut, as was the case with all the other shafts previously hewn in the same quarry. We may question whether, with the ingenuity and science of the present day, our engineers are capable of raising weights with greater facility.

Glass.—It is probable, from the evidence of painted representations, that the Egyptians were acquainted with the art of glass-blowing, 3500 years ago. These paintings represent workmen engaged in this process over a fire. A glass bead has been found, bearing the name of one of the kings, who lived about the year 1500 B. C. Pieces of glass are often found in the sarcophagi of mummies.

Glass windows, not being needed, were probably not used by the Egyptians, but their vases of that material, and their glass ware, were of great celebrity. They even excelled in one branch of the art, of which work-

men of the present age are ignorant. Specimens of manufactured glass exist, which not only present various-colored devices on the exterior, but the same hues and devices are found to pass in right lines from the surface through the body of the material, so that, by cutting off a stratum, a perfect resemblance of the first picture is reproduced. The details are remarkably distinct, the single lines of extreme delicacy, and the colors brilliant. It is supposed that the specimen is composed of glass filaments the length of which corresponds to the thickness of the plate, and which are cemented together by heat, and resemble mosaic work in principle, although the distinction of parts is entirely imperceptible.

Precious stones were also imitated with great success. Even small figures, scarabæi, and other objects usually made of porcelain, were counterfeited by earthenware covered by a vitrified exterior.

Glass was used for beads, bottles, vases, and other utensils. Among other proofs of the skill of the Egyptians in its manufacture, may be mentioned vases, which, from the manner in which the layers of color are united, have been mistaken for sardonyx.

Their glass porcelain, a vitrified composition, was remarkable for the brilliancy of its colors, proving that the Egyptians were not unacquainted with some parts of practical chemistry. This material is not unlike the porcelain glass invented by Reaumur, who changed glass into a substance resembling china ware. Its ground is generally blue or green, traversed by lines and devices of other colors executed with wonderful accuracy in detail. The picture is not confined to the surface, but extends, partially or entirely, through the substance. Particular colors, and also the handle, rim, and base, were added to the vases by a second application of heat.

It appears that the art of *cutting* glass was known to the Egyptians, and it is affirmed by Pliny that precious stones were cut and engraved by the diamond at a remote period. In the tombs of Thebes have been discovered bottles supposed to be of Chinese manufacture. From their size, and their very inferior quality compared to those

of the Egyptians, it is inferred that they were valued for their contents only.

Linen.—The Egyptians, from a very remote era, were celebrated for the manufacture of linen. It was made in great quantities and purchased extensively by foreign nations. It is ascertained that the mummy-cloths are composed entirely of that material. The aid of powerful microscopes has proved that linen fibres are cylindrical, transparent, and articulated, while those of cotton resemble a flat riband, with a border at each edge. On examination of the bandages of the mummies by this test, the fact of their being exclusively linen is decided. Linen was the conventional dress of the priests, and was extensively worn by the people.

The Egyptian looms appear to have been of very rude construction, a circumstance which renders the extreme fineness of the linen more remarkable. Specimens of the material now existing resemble silk to the touch, and in texture are equal to our finest cambrics. The great mass of the mummy-cloths are coarsely woven, but the texture of many is strikingly even, firm, and elastic. The greatest peculiarity of the Egyptian manufacture lies in the fact, that the threads of the warp invariably exceed in number those of the woof, amounting to double, treble, and quadruple the number of the latter. This fact was probably owing to the difficulty and tediousness of getting in the woof when the shuttle was thrown by hand, which is still the practice in India, and was formerly universal in Europe and this country. Some of the cloths are fringed at the ends. Three or four threads twisted together to form a strong one, and two of these again twisted together, and knotted at the middle and at the end to prevent unravelling, form the fringe, precisely as in the silk shawls of the present day. When the dresses were made up, if the fringe was wanting, the edge of the robe was hemmed.

The selvages of the Egyptian cloths are very carefully formed, and must have been strong and durable. Fillets of strong cloth or tape were also used to secure the ends of the pieces, showing a knowledge of the little resources of

modern manufacture. Several of the specimens are bordered with colored stripes of various patterns. The width of the stripes is from half an inch to an inch and a quarter. In a limited way, they resemble a modern gingham. The color was imparted to the threads, before the cloth was made. Blue is the predominant color, and this is ascertained by experiment to have been indigo.

Painted representations show that these manufactures were worn at a very early period; and the Arabians wear shawls with the same borders at the present day. One remarkable specimen now preserved is covered with hieroglyphics delineated with exquisite fineness.

The threads used for nets were also extremely fine. A linen corslet is mentioned both by Pliny and Herodotus, each of the threads of which consisted of three hundred and sixty-five fibres. The art of embroidering in gold thread was also known to the Egyptians. Their netting-needles, some of which remain, were of wood, split at each end, between ten and eleven inches long. In shape they strongly resemble our own. Others were of bronze with the point closed.

It is evident from the writings of Pliny that *mordants* were used for the purpose of dyeing, although it is uncertain whether the Egyptians understood the manner in which the salts and acids of the mordants acted, or calculated their effects solely from experience.

The yarn seems all to have been spun by the hand. Paintings now extant represent some of the looms as horizontal. Herodotus relates that instead of pushing the woof upwards, the Egyptians press it down. In a painting at Thebes the manufacturer appears to push the woof upwards, the cloth being fixed above him to the upper part of the frame.

The spindles were small, generally upwards of a foot in length. One was found at Thebes containing some of the linen thread. They were commonly of wood. To increase their impetus in turning, a circular head was attached, made of gypsum, or a composition, or of plaited rushes or palm-leaves, with a loop for securing the twine after it was wound.

The steeping, and the process of beating the stalks of flax with mallets, are thus described by Pliny. "The stalks are immersed in water, warmed by the sun, and are kept down by weights. The membrane, or rind, becoming loose is a sign of their being sufficiently macerated. They are then taken out and repeatedly turned over in the sun, until perfectly dried, and afterwards beaten by mallets on stone slabs. That which is nearest the rind is called *stupa*, 'tow,' inferior to the inner fibres, and fit only for the wicks of lamps. It is combed out with iron hooks, until all the rind is removed. The inner part is of a whiter and finer quality. After it is made into yarn, it is polished by striking it frequently on a hard stone, moistened with water; and when woven into cloth, it is again beaten with clubs, being always improved in proportion as it is beaten."

They also parted and cleansed the fibres of the flax with a sort of comb, probably the iron hooks mentioned by Pliny, two of which, found with some tow at Thebes, are preserved in the Berlin Museum; one having twenty-nine, the other forty-six teeth.

Besides the process of making cloth, that of smoothing or calendering is represented in the paintings. For smoothing linen after washing, a wooden substitute for what we call a flat, or sad-iron, was used by the Egyptian washerwomen, some of which have been found at Thebes, six inches in length, made of tamarisk wood.

Cotton.—Cotton cloth was among the manufactures of Egypt, and was worn occasionally by all classes, although the use of linen was more universal. A great quantity was used for covering the furniture of their houses, and for various other purposes. A sort of cloth was also made of the united filaments of flax and cotton.

Woollen.—The woollen manufactures of the Egyptians were highly esteemed by foreign nations. In Egypt they were used by the lower orders, and on particular occasions by the rich. The priests were permitted to wear an upper garment of this material, but under garments of wool were forbidden, and no one was allowed to be buried in a woollen covering. Carpets were made of wool, but

the fragments in the tombs have been very imperfectly preserved. A small rug has lately been brought to England made with woollen threads on linen strings. From the combination of colors, the device of the border, and a hieroglyphic, it is probably of Egyptian manufacture.

Some kinds of rope and twine were made of flax. Large ropes, intended for common purposes, were made of the fibres of the date-tree, and many specimens of these materials are still found.

Sieves were often made of strings, but some of an inferior quality, and for coarse work, were constructed of small thin rushes or reeds; a specimen of which kind of sieve is preserved in the Paris Museum.

Writing Materials.—The Egyptians were not less famed for their manufacture of paper, than for the delicate texture of their linen. The plant from which their paper was made, now called *Cyperus papyrus*, was cultivated in marshy land. For a description of the material manufactured, see Chapter VII. It was afterwards superseded by parchment. For common purposes pieces of broken pottery, slabs of limestone, wooden panels, and leather rolls were frequently substituted.

Leather.—In the tanning and preparation of leather, the Egyptians evinced considerable skill. The specimens of this art are not well preserved, but the straps placed across the bodies of the mummies at Thebes, from their fineness and the beauty of their figures, prove the skill of the leather-cutters, and the antiquity of embossing. Some of these bear the names of kings who reigned 3300 years ago. From the paintings, we ascertain that they made shoes, sandals, parasols, and the coverings and seats of chairs or sofas, which were painted with flowers and fancy devices; also the ornamental furniture of the chariot, and skins for carrying liquids, coated with a resinous substance. The skins were cured and dyed. Their instruments do not appear to have been numerous. The most remarkable was the semicircular knife, which obtained the longest thongs from a circular piece of leather by cutting it spirally, as is done at the present day. For tanning, they used the pods of the Acacia Nilotica.

Trades.—The potters were a numerous class, and all the processes belonging to their art, of mixing the clay, and of turning, baking, and polishing the vessels, are represented in paintings in the Theban tombs.

The occupations of the carpenters and cabinet-makers form an important subject in the paintings which represent the Egyptian trades. Among their tools were the axe, adze, handsaw, chisels of various kinds, (which were struck with a wooden mallet,) the drill, two sorts of planes, the ruler, plummet, and right angle or square, a leather bag containing nails, the hone, and a horn of oil. The paintings also attest the invention of *glue* 3300 years ago, and several wooden boxes have been found in which the joints are fastened by this material. They were acquainted with dovetailing, and practised the art of applying two planks together in the same plane by means of broad flat pins, or tongues of hard wood. The blades of the tools found at Thebes are always of bronze, the handles of the acacia, or tamarisk wood; the blade being fastened to the handle by thongs of hide. Many of them bear the signs of having been beaten with the hammer. The hatchet was used by boat-builders. The art of veneering is distinctly noticed in some of the sculptures of Thebes.

Furniture.—The furniture of the Egyptians evinced great taste and skill. It consisted of chairs, fauteuils, couches, ottomans, bedsteads, tables, and stools, of great variety and beauty. Many fauteuils or lolling chairs were made of ebony inlaid with ivory, covered with rich stuffs, and very similar to some now used in Europe. None of these have as yet been found, but more ordinary chairs of smaller size have been discovered at Thebes, the seats of which are of wood, or of interlaced strings, or leathern thongs, not very unlike our own rush-bottomed chairs. The fauteuils were of different forms and height, the legs usually in imitation of those of a wild animal, and not requiring the support of a cross-bar. The back was light and strong, in most instances receding gradually, and terminating at the summit in a graceful curve, supported from without by perpendicular bars. Over this

was thrown a pillow of colored cotton, painted leather, or gold and silver tissue. Some of the stools folded up on the principle of our camp stools. Footstools were also in use. The couches of the Egyptians were elegantly formed, and were very probably used as bedsteads at night. The custom of reclining on them at meals, afterwards practised by the Romans, does not appear to have been yet introduced. The tables were of wood, metal, or stone, and were round, square, or oblong. The round ones were supported by a single shaft, sometimes representing the figure of a captive. Large tables had three or four legs, or were made with solid sides. The pillows of the bedsteads were of wood, or of elegantly-carved alabaster. One found at Thebes is of wood, in the form of a half cylinder supported by a pedestal.

Their boxes were of various forms and materials. One of those found at Thebes is made of ebony, inlaid with ivory painted with remarkable brilliancy. The lids were curved, flat, or pointed. They were made to slide into a groove, or to turn on hinges of various forms. Some turned on a single pin at the back; others were divided into two parts, one of which turned on two small pins at the base, on the principle of the doors of their houses and temples. The cover of large boxes was separate.

With the carpenters, may be mentioned the wheelwrights, the makers of coffins, and the coopers. This subdivision of one class of artisans, showing a systematic partition of labor, is one of the many proofs of the advancement of this civilized people. Their vehicles were the chariot, curricle, and plaustrum or travelling car drawn by oxen. They were of wood, and were made chiefly by the carpenter and currier.

Boats.—A common class of boats were made of water-plants or osiers bound together by the stalks of the papyrus, and were very light. Moses is related to have been exposed in an ark (or boat) of bulrushes daubed with slime and pitch, which last matèrial was undoubtedly used by the Egyptians. The large boats of burden were made of wooden planks, and contained spacious cabins. Boats were furnished with oars, masts, sails, rudders, and

ropes. They had galleys and ships of war, differing from the small boats in construction as well as size.

Dress.—The dress of the Egyptians was generally of linen. They occasionally wore a cloak of wool, and the priests a dressed leopard's skin, ornamented. Their heads were shaven, and wigs were substituted for hair, specimens of which have been recently discovered. Their sandals displayed a variety of forms. The ladies wore jewels elaborately made of gold, silver, and precious stones, frequently engraved with devices and hieroglyphics. Their shapes were extremely various. The lower classes wore ornaments of ivory, blue porcelain, and occasionally of the common metals. Signets were used by Egyptians of rank. One of these, still preserved, contains twenty pounds' worth of gold.

Ointments were employed at the toilet of ladies, and a specimen, now in England, has retained its odor for two or three thousand years. Combs were usually of wood. The custom of staining the eyelids and brows with a moistened powder of a black color was common from the earliest times. Jezebel is said to have painted her face when Jehu came to Jezreel. The same custom is mentioned in Jeremiah and Ezekiel. Pins and needles were in use, and have been occasionally found. The former are frequently long, with large gold heads ; others appear to have been used for arranging the hair. Some needles were of bronze. Mirrors were made of mixed metal, chiefly copper highly polished, inserted into handles of various shapes and materials. Canes made of hard wood were used by the Egyptians in walking, from four to six feet long.

Among the remarkable inventions of this remote era, may be mentioned bellows and syphons. Artificial flowers were manufactured for ornamental purposes. The musical instruments were the harp, lyre, guitar, tambour, double and single fife, flute, and some others. The drinking cups of the Egyptians were of gold, silver, glass, porcelain, alabaster, ivory, and earthenware. Their vases and baskets were very various and beautiful.

It is worthy of remark, that not only a variety of

costly ornaments are found, but likewise successful attempts to imitate these by the use of humbler and cheaper materials. This fact, says Mr. Wilkinson, strongly argues the great advances which this people had made in the customs of civilized life, since it is certain that until society has arrived at a high degree of luxury and refinement, artificial wants of this nature are not created, and the lower classes do not yet feel the desire of imitating their wealthy superiors in the adoption of objects dependant on taste or accidental caprice.

Metals and Minerals.—The Egyptians appear to have been acquainted with many of the most useful metals and minerals, and their compounds, such as gold, silver, iron, copper, brass, bronze, lead, tin, granite, basalt, porphyry, serpentine, breccia, earthenware, alabaster, glass, and porcelain. They also employed bone, ivory, wood, shell, and ebony. Gold was engraved, cast, and inlaid, or hammered into gold-leaf, and employed for gilding bronze, stone, silver, and wood. Much gold was used for vases and female ornaments, for statues, baskets and other purposes. The faces of mummies are frequently found overlaid with thick gold-leaf. Although stamped money is not known to have been used by the ancient Egyptians, we have evidence of weights and measures for the weighing of gold having been invented by them, long before the Greeks existed as a nation. Gold-mines were wrought in Egypt, as hereafter described. Other metals were used for arms, vases, statues and implements of every kind, articles of furniture and numerous other objects. For ordinary purposes, bronze appears to have been extensively employed, especially for tools. This metal was compounded with consummate skill; the numerous methods that were adopted for varying its composition are shown in the many qualities of the specimens which have been discovered. They had the secret of giving to bronze or brass blades a certain degree of elasticity, as may be seen in a dagger now preserved in the Berlin Museum. The period of the introduction of iron is uncertain; it was probably of later date than that of bronze. The specimens of tools of the latter metal are

much more numerous, which may perhaps be accounted for by the fact of its resisting better the influence of time, and the usual causes of decay. The hieroglyphics on obelisks and other granitic monuments are sculptured with a minuteness and finish which modern sculptors seldom surpass. If these were cut by implements of bronze only, we must confess that the Egyptians possessed certain secrets in hardening or tempering bronze, with which we are at this day unacquainted. There exists on the lid of a granite coffin, the figure of a king reposing in high relief, which is raised to nine inches above the level of the surface.

Gold-mines existed in Egypt, and were worked by captives and prisoners. A description of their state is given by Diodorus, as it existed in his own time.

"The soil," says this historian, "naturally black,* is traversed with veins of marble of excessive whiteness, surpassing in brilliancy the most shining substances; out of which the overseers cause the gold to be dug by the labor of a vast multitude of people; for the kings of Egypt condemn to the mines notorious criminals, prisoners of war, persons convicted of false accusations, or the victims of resentment. And not only the individuals themselves, but sometimes even their whole families are doomed to this labor, with the view of punishing the guilty and profiting by their toil.

"The vast numbers employed in these mines are bound in fetters, and compelled to work day and night without intermission and without the least hope of escape; for they set over them barbarian soldiers who speak a foreign language, so that there is no possibility of conciliating them by persuasion, or the kind feelings which result from familiar converse.

"When the earth containing the gold is hard, they soften it by the application of fire, and when it has been reduced to such a state that it yields to moderate labor, several thousands (myriads) of these unfortunate people break it up with iron picks. Over the whole work presides an

* The rock in which the veins of quartz run, is an argillaceous schist.

engineer, who views and selects the stone, and points it out to the laborers. The strongest of them, provided with iron chisels, cleave the marble-shining rock by mere force without any attempt at skill; and in excavating the shafts below ground they follow the direction of the shining stratum, without keeping to a straight line.

"In order to see these dark windings they fasten lamps to their foreheads, having their bodies painted, sometimes of one and sometimes of another color, according to the nature of the rock. As they cut the stone it falls in masses on the floor, the overseers urging them to the work with commands and blows. They are followed by little boys, who take away the fragments as they fall and carry them out into the open air. Those who are above thirty years of age are employed to pound pieces of the stone of certain dimensions with iron pestles in stone mortars, until reduced to the size of a lentil. It is then transferred to women and old men, who put it into mills arranged in a long row, two or three persons being employed in the same mill, and it is ground until reduced to a fine powder.

"No attention is paid to the persons of the prisoners; they have not even a piece of rag to cover themselves; and so wretched is their condition, that every one who witnesses it, deplores the excessive misery they endure. No rest nor intermission from toil is given either to the sick or maimed; neither the weakness of age, nor women's infirmities are regarded. All are driven to their work with the lash, till, at last, overcome with the intolerable weight of their afflictions, they die in the midst of their toil. So that these unhappy creatures always expect worse to come than what they endure at the present, and long for death as far preferable to life.

"At length the masters take the stone thus ground to powder, and carry it away to undergo the final process. They spread it upon a broad table a little inclined, and pouring water upon it, rub the pulverized stone until all the earthy matter is separated, which, flowing away with the water, leaves the heavier particles behind on the board. This operation is often repeated, the stone being rubbed

lightly with the hand. They then draw up the useless and earthy substance with fine sponges gently applied, until the gold comes out quite pure. Other workmen then take it away by weight measure, and putting it, with a fixed proportion of lead, salt, a little tin and barley bran, into earthy crucibles well closed with clay, leave it in a furnace for five successive days and nights; after which it is suffered to cool. The crucibles are then opened, and nothing is found in them but pure gold a little diminished in quantity."

It would require volumes, and indeed many have been already written, to exhibit the power, the customs, and the arts, which prevailed in ancient Egypt. It is to be regretted that superstition and cruelty were in so extensive a degree made agents by which this remarkable people accomplished their extraordinary undertakings, in a period of the world so remote, that we are accustomed to consider them as original pioneers in the great work of human civilization.

Many circumstances, says Mr. Wilkinson, unite in proclaiming that civilization existed in Egypt at least as early as the eighteenth century before the Christian era. How far does this throw us back into the infancy of the world! at least of the world peopled by the descendants of Noah. And when we recollect that the pyramids of Memphis were erected within three hundred years after the era assigned to the Deluge, and that the tombs of Beni Hassan were hewn and painted with subjects describing the arts and manufactures of a highly-civilized people about six hundred years after that event, it may occur that the distance between the Deluge and the construction of those pyramids and tombs is not greater than from the present day to the reign of Elizabeth and of Henry III.

ARTS OF THE ASSYRIANS.

In an early period of the world, the Assyrians cultivated the arts, and are celebrated as having excelled in that of architecture. According to some historians, Belus, known in the Scriptures by the name of Nimrod, the first king of Assyria, built the city of Babylon, where he

arrogated to himself the honors of divinity. Ninus, his son, erected to him the first known temple, consecrated a statue to his memory, and ordered it to be worshipped by his subjects.

All historians agree that Babylon was a large and beautiful city. Pliny relates that it was sixty miles in circumference; that its walls were two hundred feet high, and fifty thick; and that the magnificent temple of Jupiter Belus was standing there in his time. Herodotus says, that it was four hundred and eighty furlongs in circumference; that it was full of magnificent structures, and celebrated for the temple of Belus; that it had a hundred gates of brass, which, if true, proves that the fusion and alloying of metals were known at that time.

This statue of Belus was constructed about two hundred years after the flood, and is supposed to be the same idol mentioned in the Scriptures under the name of Baal. Ninus was the founder of the city of Nineveh, of which Diodorus says, the city was four hundred *stadia*, or, if reduced to English measure, fifty miles in circuit, and which is described in the book of Jonah as an exceeding great city of three days' journey.

Semiramis, the wife of Ninus, finished in this age the stupendous walls of Babylon, which were reckoned among the seven wonders of the world. This princess, to whom the administration of government was left by her husband, ascended the throne about seventeen hundred years before Christ. Diodorus and other ancient writers relate, that among the works executed by Semiramis, she caused the images of all kinds of animals to be sculptured in *relievo* on the walls of her palace, and had them colored after nature. These figures, they say, were more than four cubits high. In the middle appeared Semiramis piercing a tiger with her dart, and near her, her son Ninias slaying a lion with his lance. In another part of the same palace, were the statues of Jupiter Belus, Ninus, Semiramis, and of her principal officers of state. These statues, they say, were of bronze. They further add, that three statues of massy gold, representing Jupiter, whom the Babylonians called Belus, Juno, and Rhea, were erected by her, on the sum-

mit of a temple dedicated to Jupiter Belus, and erected by the command of Semiramis in the middle of Babylon.

These works however shrink into trifles when compared with that which the same author informs us this great Queen caused to be executed on the mountain Bagisthan. This mountain, which, according to Diodorus, on one side presented a rugged rock sixteen furlongs in perpendicular height, she caused to be sculptured into a group of colossal statues. Paolo Lomazzo says, the mountain was seventeen furlongs in circumference, and was carved into a group of a hundred of her guards, and other of her subjects, offering sacrifice to her.*

The *walls* and *hanging gardens* of Babylon were among the ancient wonders of the world. They were built on arches at a great height from the ground, were watered from the river, and presented a succession of terraces upon which plants, and even trees of the largest size were cultivated.

The ruins of Babylon at the present day furnish little to illustrate the former splendor of that city. Vast and shapeless heaps of sun-dried bricks, mostly of square form, containing reeds, and inscribed with characters of an extinct language, are almost the only vestiges which mark the site of that ancient capital on the banks of the Euphrates.

ARTS OF THE HINDOOS.

The principal remains of the ancient Indian, or Hindoo style of architecture, which have been hitherto discovered, are of a peculiar kind, being mostly excavations in the solid rock. Immense subterraneous temples are still to be seen in various parts of India, presenting extraordinary monuments of the skill and industry of the people who achieved them. These subterraneous caverns are apparently as ancient as the oldest Egyptian temples, and M. D'Ancarville even thinks them anterior to the time of about two thousand years before Christ. The most remarkable of these excavations is at Elephanta, a small island in the harbor of Bombay. An elephant of

* Elmes's Lectures on Architecture.

black stone, large as the life, is seen near the landing-place, and most probably gave name to the island. The cavern is about three quarters of a mile from the beach. It is formed in a hill of stone and is one hundred and thirty-five feet square, and nearly fifteen feet high, having its massy roof supported by rows of columns, regularly disposed. Gigantic figures in relief are executed on the walls; which, as well as the columns, are shaped in the solid rock. The form of the columns, although doubtless inferior to the Grecian in beauty, is, however, more agreeable to the eye of taste than some of those of the Egyptians. The capitals resemble round cushions, pressed down by the incumbent weight.

The excavations in the island of Salsette, which is about ten miles north of Bombay, are among the architectural wonders of India. The artist employed by Governor Boon to make drawings of them, asserted, that it would require the labor of forty thousand men for forty years to finish them. They are found near to Ambola, a village about seven English miles distant from Tanna.

The temple, or pagoda, is entered by a doorway, which is twenty feet in height, and leads to the grand vestibule. At the end of this is the real door of the temple, on the two sides of which are sculptured various figures in relief. The temple itself is a square cell, of about twenty-eight feet. The upper part of this is supported by twenty columns nearly twenty feet high, of a form resembling in style those of Elephanta.

There is another rock entirely excavated into similar caverns, but of different shapes and dimensions, and equal in beauty to those before mentioned. Some of these caverns are very lofty, and appear to have been divided into two stories as if for habitation. Their want of sculpture also strengthens this surmise. They have apertures cut for light above, and square holes in each side of the rock, at an equal height on both sides, and opposite to each other, as if for the purpose of receiving joists or beams of timber.

The height of the excavation of Indur Subba is forty feet, its depth fifty-four, and its breadth forty-four.

The height of the obelisk by the side of the pagodas is twenty-nine feet, including its pedestal and the group of human sitting figures which is on the top. The obelisk is fluted and ornamented with some taste, and has a light appearance. On the other side is the representation of an elephant without a rider, whose back just rises above the front wall. The plans of these excavations are as regular as if built; and the piers and pilasters or square pillars are equidistant, and sculptured in a bold and original style.

The most learned of the eastern antiquaries, members of the Asiatic Society, differ as to the periods of these excavations. They are undoubtedly of most remote antiquity, and appear to be derived from the same elements, if not from the same people, as those in Egypt.

ARTS OF THE PERSIANS.

The architectural ruins which still exist of that great empire which is improperly called by Europeans, *Persia*, a name which belonged to a single province of the whole empire of *Iran*, are conclusive evidences of the grandeur of the ancient inhabitants. They differ in style both from the Egyptian and Hindoo, yet possess a general affinity with them. Sir William Jones, after due investigation, concludes that the Iranian or Persian monarchy must have been the oldest in the world; but is doubtful to which of the three stocks, Hindoo, Arabian, or Tartarian, the first kings of Iran belonged. He also holds, that Iran, or Persia, in its largest sense, was the true centre of population, of knowledge, of languages and of arts. An account of the architecture of such a people cannot but be of consequence, and it is therefore to be lamented that so few faithful delineations of their buildings have as yet been made.

The ruins of Persepolis constitute the most remarkable remains of Persian architecture. The first objects that meet the traveller at the present day on his entrance into the limits of this city, are two portals of stone, about fifty feet in height, the sides of which are embellished with two sphinxes of immense size, dressed

with a profusion of bead-work, and, contrary to the usual method, represented in a standing posture. On the sides above are inscriptions in an ancient character, the meaning of which no one has been able to decipher. At a small distance from these portals, you ascend another flight of steps, which lead to the grand hall of columns. The sides of this staircase are ornamented with a variety of figures in bas-relief, most of them having vessels in their hands: here and there a camel appears, and at other times a kind of triumphal car made after the Roman fashion; besides which there are several led horses, oxen, and rams, that at times intervene and diversify the procession. At the head of the staircase is another bas-relief, representing a lion seizing a bull; and close to this are other inscriptions in ancient characters. On arriving at the top of this staircase, you enter what was formerly a magnificent hall. The natives have given this the name of *chehul minar*, or forty pillars; and though this name is often applied to the whole of the building, it is more particularly appropriated to this part of it. Although a vast number of ages have elapsed since their foundation, fifteen of these columns yet remain entire; they are from seventy to eighty feet in height, their pedestals are curiously wrought and appear little injured by time. They are formed of a beautiful white marble, fluted to the top, and the capitals are adorned with a profusion of fretwork and surmounted with a figure of some animal. The well-known circumstance, of the ancient Persians performing their religious rites in the open air, proves, says Mr. Elmes, in opposition to the opinion of Millin, that it was an ancient Persian temple, for the building could never have had architraves, or a roof.

From this hall you proceed along eastward, until you arrive at the remains of a large square building, which is entered through a door of granite. Most of the doors and windows of this apartment are still standing; they are of black marble, polished like a mirror. On the sides of the doors, at the entrance, are bas-reliefs of two figures at full length, representing a man in the attitude of stabbing a goat. Over another door of the same

apartment is a representation of two men at full length; behind them stands a domestic holding a spread umbrella; they are supported by large round staves, appear to be in years, have long beards, and a profusion of hair upon their heads.

At the southwest entrance of this apartment are two large pillars of stone, upon which are carved four figures, dressed in long garments, and holding in their hands spears ten feet in length. At this entrance, also, the remains of a staircase of blue stone are still visible. Vast numbers of broken pillars, shafts and capitals are scattered over a considerable extent of ground, some of them of enormous size.

ARTS OF THE HEBREWS.

The Hebrews, Israelites, or Jews, by a residence in Egypt of nearly four hundred years, had attained a considerable degree of civilization. After their deliverance from slavery in that country, they led a wandering life for forty years. The temples which they had seen in Egypt, dedicated to the Egyptian idols, led them to consecrate a temple, where they might assemble in public worship of the true God. As it was necessary, from their mode of life during their sojournment in the wilderness, that it should be portable, they constructed it in the form of a spacious tent. In the plan and general appearance of this temporary building, known by the name of the Tabernacle, they took, it has been conjectured, the form of the Egyptian temples for their guide; but in the details and ornaments, they adopted a peculiar and national style. The whole court enclosing the tabernacle when at rest, according to Calmet and the best authorities, covered a space of one hundred biblical cubits by fifty cubits wide; and the enclosure, five cubits high, was formed of wooden columns, with brass bases and silver capitals, having curtains of tapestry suspended between them. These columns were sixty in number, twenty on each side which lay north and south, and ten on each side which faced the east and west. The Jews used this movable temple for a length of time after the conquest of

Palestine; but, under the reign of Solomon, they constructed a permanent temple at Jerusalem.

David, the father of Solomon, had made considerable preparation for its construction, which was greatly facilitated by the alliance of the Jews with the Tyrians, who furnished them with architects, workmen, and the necessary timber. The accounts of this building, transmitted to us by the Bible, are not sufficiently distinct to enable us to form a precise idea of its entire plan; nor have other authors removed all obscurity. The clearing of the site of this temple, a work of immense labor, was begun under the reign of David, and the whole structure finished and dedicated by Solomon.

The summit of Mount Moriah formed a plain of thirty-six thousand three hundred and ten square feet. They began by levelling the top and sides of the mountain, against which they afterwards built a wall of freestone, four hundred cubits high. The circumference of the mountain, at the foot, was three thousand cubits. Upon the plain was built the temple, divided, like the tabernacle, into two divisions, by a partition of cedar. Under the second division, or the sanctuary, it appears, they preserved the treasures of the temple.

In the principal front was the Ulam, probably a grand portico, such as exists in several Egyptian temples. The temples of the ancients were generally without windows, but that of Jerusalem appears to have had them, and of the same form as those observed in the ruins of Thebes. The timbers of the ceiling were of cedar, and it appears that the roof was flat like those of the Egyptian temples.

Round the temple was a wall or enclosure, and the space between that and the temple was occupied by a porch divided into three stories. The principal edifice was preceded by two courts; the first and largest was for the assembly of the people; in the second, called the priests' court, was the temple. It was surrounded with apartments or houses, which were for the lodgings of the priests, for the preservation of the instruments used in sacrifice, and to confine the beasts, &c.

Before the Ulam were two columns of brass, twelve cubits in circumference, and eighteen in height, without reckoning the capitals, which were executed in bronze, and five cubits high These capitals resembled, according to the expression of the Bible, "lily work," which indicates some resemblance to the Egyptian capitals, composed from the lotus-flower. There is no mention made of vases, and it is possible that they had none.

The exterior walls of the temple were of stone, squared at right angles, and ornamented with the figures of cherubim, palm-leaves, flowers, &c., sculptured probably in the stone like the Egyptian hieroglyphics. The roof was covered with plates of gold, and the interior decorated in the richest manner. Besides this temple, Solomon erected many other works, as the walls of Jerusalem, several public granaries, stables, &c.

The accounts of this building, given to us in the books of the Old Testament, are too well known to need repetition here; but they are not sufficiently technical to give an exact architectural idea of its construction.

ARTS OF THE GRECIANS.

The discoveries and inventions of the Egyptians were carried into Greece at an early period in the history of that nation. The communication between these two countries was made, first by the Phenicians, the most distinguished commercial people of their time, and afterward by the travels of many lawgivers and philosophers of the Greek nation, who visited Egypt, attracted by the fame of that comparatively civilized region, and anxious to introduce among their own countrymen the improvements in which the inhabitants of the banks of the Nile had gone so far beyond their contemporaries. Homer, Lycurgus, Solon, Pythagoras, and Plato are among the distinguished Grecians who made this tour of instruction.

It is not necessary to recapitulate among their acquisitions the various arts of agriculture, navigation, mechanics, and domestic economy;—arts which appertain so intimately to the necessities of life, that when once discovered, they may be said to be never forgotten. It is sufficient

to know that the Greeks built large and splendid cities, constructed and equipped powerful fleets, wrought, from most of the useful metals, tools, weapons and armor, among which were manufactures of iron, and probably of steel; that they wove and dyed fabrics of various workmanship and materials, and, in short, appear to have arrived at the possession of most objects of use, luxury, and ornament, which in that day could gratify the wants of a refined and intelligent people.

Among the objects which have been found on opening the tombs of the ancient Greeks, are small urns and lachrymatories of potters' ware, swords, arrow-heads and bullets for slings, masks, lyres of wood resembling the shell of a tortoise, coins, dresses, iron fetters, bowls, mirrors of metal, combs made of boxwood, bird-cages of pottery having threads for bars, inscriptions, images, bas-reliefs, &c. &c.

Architecture.—The Greeks, in their earliest works, had imbibed from the Egyptians a taste for massive and substantial architecture. The Cyclopean walls, the remains of which are still extant, show their acquaintance with the means of lifting and adjusting in their place stones of prodigious magnitude. It is said that mortar was seldom used by the Greek builders, and that they appear to have relied, for stability, upon the size and accurate finish of the stones which they laid.

But the great fame of this cultivated people rests upon their progress in the arts of imitation and design, and in the possession of qualities which led them to excel in the conception of beauty and fitness of form, as they did at the same time in the combinations of poetry and eloquence. Their style of ornamental architecture has been the admiration of all succeeding ages, and their sculpture has furnished models, which we now strive to imitate, but do not pretend to excel.

The Grecians introduced the Doric order in architecture, of which the oldest and most massive specimens now remaining, are in the Grecian colonies of Sicily and southern Italy. This order was afterwards carried to perfection in the Parthenon, or temple of Minerva at

Athens, built during the time of Pericles. The symmetry of this building has never been questioned; and the sculptures which decorated its entablature, a part of which, under the name of the Elgin marbles, are now in London, though mutilated and defaced, are studied and admired by all who appreciate true excellence in art.

The Ionic and Corinthian orders had also their origin in Greece. Specimens of both are still extant at Athens, the former in the temple of Erectheus, and the latter in the Choragic monument of Lysicrates. They are also found in other parts of Greece, and were introduced into Italy at a later period than that of the buildings already mentioned, and became the groundwork of Roman magnificence.

Sculpture.—Of the sculpture of Phidias and Praxiteles it is unnecessary to speak. These artists and their contemporaries have given to Grecian statuary a fame and an eminence, to which the world has ever since been unanimous in its homage. Rome was enriched by Grecian statues, either carried off, at the conquest of the Grecian states, or executed for the Romans by Grecian artists.

Painting.—The art of painting appears to have flourished in Greece. Although we cannot judge, as in Egypt, of the state of this art, from specimens actually existing at the present day, yet the eminence acquired by some of the Grecian painters, as Zeuxis, Parrhasius, and Apelles, could not have been accorded to them by so enlightened and discriminating a people as the Greeks, unless painting had advanced to the same perfection which was attained by its sister art of sculpture.

ARTS OF THE ROMANS.

The Romans derived from Greece their principal knowledge of the arts, sciences, and literature. During the earlier periods of the republic, no great advances were made by them in the improvement of their condition. Their public works were few in number, and their private houses are said to have been miserable wooden huts, so that the burning of the city by the Gauls under Brennus

has been thought a benefit rather than an evil. All other arts being at this time absorbed in the art of war, the only works of magnitude which have remained as monuments of the constructive skill of the early Romans, are some works of practical utility, such as their *cloacæ*, a sort of subterranean passages, or streets, constructed at a vast expense for the purification of the city.

Architecture.—After the conquest of Greece and Asia, the arts, in common with the luxuries of the East, began to be introduced into Rome. Individuals began to gratify their taste by the erection of expensive mansions, and rulers to promote their popularity by splendid temples, theatres, and monuments. During the repose of the Augustan age, not only in Rome itself, but in Italy and the provinces, there arose, as if by common consent, a multitude of rich and costly edifices. Augustus boasted, on his death-bed, that he had found Rome of brick and had left it of marble. The Pantheon, or temple of all the gods, which is now standing, the most perfectly preserved monument of the ancient city, was built in the reign of Augustus. From this period, the luxury and extravagance of building increased with rapid strides. The models of Greece were loaded with adventitious decorations, and the Corinthian and Ionic were combined to form a new order, the *Composite*. No materials were esteemed too costly, and no workmanship too exquisite, to form a part of Roman magnificence. Nero expended the public treasures in the erection of a dwelling-house for himself, which, from the profusion of its ornaments, was called the *golden house*. It had three porticoes, each a mile in length, supported by a triple row of pillars. A colossal statue of Nero which stood in the vestibule, was one hundred and twenty feet in height. The ceilings of the palace were incrusted with gold, gems, and ivory panels. That of the principal banqueting-room revolved upon itself, representing the motions of the heavens. Showers of perfumes, and baths of different waters brought from a distance, were added to the luxuries of the place, and the tyrant condescended to say, that "he had at last got a house fit for a man to live in."

Vespasian, who succeeded after a short interval to the imperial purple, wisely foreseeing that the popularity of an emperor would be less promoted by the magnificence of his private dwelling, than by that of his public works, caused the splendid house of Nero to be demolished, and upon its ruins he commenced the building of the Colosseum, an amphitheatre of public sports, a structure which fifteen thousand men were ten years in completing, and whose enormous remaining walls are the astonishment of travellers at the present day. Within the arena of this structure took place the combats of gladiators, the fights of wild beasts, and the martyrdom of many of the early Christians.

Temples.—The temples of Rome, of which there were several hundred within the city, had in most cases lofty porticoes in front, composed of rows of columns. These in some instances extended quite round the building. They were usually in the form of an oblong square, but were sometimes circular. Of both these shapes, there are specimens still extant in tolerable preservation on the banks of the Tiber.

Arches.—Triumphal arches built of marble, and decorated with columns, statues, bas-reliefs, and inscriptions, were erected by the Romans in honor of their victorious emperors. Three of these arches, bearing the names of Titus, Septimius, and Constantine, are still standing in the Roman forum. The remains of others are seen in various parts of Italy and of Europe.

Columns.—The memory of distinguished emperors was in some cases commemorated by monumental columns. The column of Trajan, still standing in good preservation at Rome, is one hundred and twenty-eight feet in height, and is ascended by a spiral staircase of stone on the inside. On the outside is a spiral line of sculptures extending from the bottom to the top, representing the exploits of Trajan. On the summit was a statue of the Emperor holding in his hand a globe of gold, in which his ashes were contained. This statue has disappeared, and is now replaced by one of St. Peter. The column of Antoninus, nearly similar in its general structure, is also in good preservation at the present day.

Aqueducts.—The aqueducts of Rome have been justly celebrated, as combining extensiveness and magnificence, with great public utility. These aqueducts were large stone channels, which conveyed streams of water to the city from a great distance. Some of them were forty, others sixty miles in length. They were carried through rocks and mountains and over valleys, supported on tiers of arches which in some cases exceeded a hundred feet in height. The remains of some of these aqueducts still exist about Rome, and in other parts of Europe. One of the best preserved is the Pont du Gard, near Nismes in France.

Roads.—Among the greatest and most expensive of the Roman works, were their public roads. These were made from Rome as a centre, and extended to all parts of the empire, even the most distant. They were carried to the Straits of Gibraltar, then called the Pillars of Hercules, to the River Euphrates, and to the southern confines of Egypt. Many of these roads were paved with stone. These pavements are seen in various places at the present day, and the ruts worn in them by wheels, give abundant evidence of the use to which they were applied. In some instances, the roads were extended through mountains by tunnels or subterranean galleries. One of these between Puteoli and Naples, at this day called the Grotto of Pozzuolo, is cut through the solid rock.

Bridges.—The Romans excelled in the construction of bridges, some of which continue in use in our own times. They were built in the most substantial manner, with piers and arches of hewn stone. The most remarkable Roman bridge, and perhaps the most wonderful in the world, was the bridge built by Trajan over the Danube. This structure was raised on twenty piers of hewn stone, one hundred and fifty feet from the foundation, the piers being one hundred and seventy feet distant from each other. The bridge was sixty feet wide, and about a mile in length. It was partly taken down by the succeeding emperor, Hadrian, to prevent the incursions of the barbarians.

Houses.—The private dwelling-houses in Rome were at first irregularly built and crowded on narrow streets. But after the conflagration in Nero's reign, in which a great part of the city was destroyed, the streets were widened, and the houses built with more regularity. The houses of the more wealthy citizens were large, and contained various apartments. Before the entrance was an empty space, called *vestibulum*, from whence a gate or door communicated with the *atrium*, or principal hall or court. There was an open place in the centre of the house, called *impluvium*, into which rain-water fell, and through which light was admitted from above. The Romans had no chimneys for carrying smoke, but built their fires in the atrium upon open hearths, or, in certain cases, conveyed heat from furnaces below the floor, by tubes or pipes affixed to the walls. Glass windows are not mentioned by any writer as having been in use before the fourth century, yet windows containing fragments of glass have been discovered at Pompeii. Windows covered with linen cloth, paper, horn, and a transparent stone, probably mica, were sometimes employed to transmit an imperfect light.

Baths.—The first Romans bathed, after exercise in the Campus Martius, in the Tiber; but soon after, they constructed private and public baths, divided into many apartments. The front of the baths was commonly to the south, and very extensive. The middle was occupied by the Hypocaust, where the fires were kept, which had on the right and left a suite of four similar rooms on both sides, so disposed that persons could easily pass from one to the other. These apartments were known by the name of *Balnearia*. The saloon of the warm bath was twice as large as the others, on account of the concourse of idlers who frequented these establishments.

The description of the Thermæ of Diocletian, by Andrew Baccius, furnishes a complete idea of Roman grandeur. He mentions a large lake for swimming, porticoes for promenades, *Basilicæ* for assembling before entering or leaving the baths, eating rooms, vestibules

and courts adorned with columns, places for procuring perspiration, delightful woods planted with planes and other trees, spots for running in, some with seats for conversation, others for wrestling and athletics. There were also libraries, and departments where poets and philosophers cultivated the sciences.

Riding.—The Romans rode without saddles, except some covering for ornament, such as the skin of a wild beast. This kind of covering is represented in the sculptures of the Emperor Trajan, on the arch of Constantine. Nevertheless, saddles of considerable size appear to have been in use in the reign of Theodosius, in the fourth century, as an edict was issued limiting their weight to sixty pounds. No certain evidence of the employment of stirrups can be found prior to the sixth century. The Greek and Roman youth were educated to vault from the ground, into their seat on horseback.

Statuary, Paintings, Implements, Domestic Arts, &c.—The most satisfactory knowledge of the economical and domestic arts of the Romans, is derived from the numerous instruments, products, and specimens of workmanship which have been dug out of the ruins of Herculaneum and Pompeii. These cities are known to have been buried in an eruption of Vesuvius, in the reign of the Emperor Titus. Excavations have been made during the past and present centuries, to a great extent, in both these cities, especially in the latter. A vast variety of articles of use and ornament, employed by the Romans, have thus been recovered in good preservation, and throw much light on the state of the arts among them at that period.

Among the objects recovered from these cities the statues may be first noticed. Many of these, says Mr. Elmes, are of the finest workmanship, and of the most difficult execution. Some are colossal, some of the natural size, and some in miniature; and the materials of their formation are either clay, marble or bronze. They represent all different subjects, divinities, heroes, or distinguished persons; and in the same substances, especially bronze, there are figures of many animals. Two statues, seven feet high, of Jupiter, have been dug out; also a woman in

clay, and two gladiators in bronze about to combat. There is likewise a statue of Nero in bronze, naked and armed as a Jupiter *Tonans*, with a thunderbolt in his hand ; a Venus of white marble, in miniature, and the statue of a female leaving the bath, besides many others.

The ancient pictures of Herculaneum are of great interest, not only from the freshness and vividness of their colors, but from the nature of the subjects they represent. All are executed in fresco ; they are exclusively on the walls, and generally on a black or red ground. It has been supposed, from passages in the classics, that the ancients used only four colors, white, black, yellow and red; but here are added blue and green. Some of them, which represent animated beings, are large as life, but the majority are in miniature. Every different subject of antiquity is depicted on these walls ; deities, human figures, animals, landscapes, foreign and domestic, and a variety of grotesque beings. Sports and pastimes, theatrical performances, sacrifices, all enter the catalogue. One of large size, found in a temple, represents Theseus vanquishing the Minotaur, which lies stretched at his feet, with the head of a bull and the body of a man. A female, supposed to be Ariadne, and three children, form part of the group. This, along with a picture composed of several figures as large as life, of which Flora is the most conspicuous, adorned a temple of Hercules ; each is six or seven feet high and five broad. Another represents Chiron teaching Achilles the lyre ; and female centaurs are seen suckling their young. The interior of a shoemaker's shop is exposed on a smaller scale ; a feast, baskets of fruit, a grasshopper driving a parrot yoked to a car, a Cupid guiding swans in the same manner, and many other allegorical subjects, are represented. The King of Naples, desirous of preserving these pictures, directed them to be sawed out of the walls,.a work of great labor and perseverance, after which they were put in shallow frames and kept in the museum.

It is extraordinary that numbers of perishable substances should have resisted the corrosions of time. Many almonds in the shells, imprinted with all the lines and

furrows characterizing their ligneous envelope, were dug out of the ruins of Herculaneum ; figs and some kinds of wild apples were in preservation ; and a pine cone yet growing in the woods of Italy, the seeds of which are now eaten, or used for culinary purposes. Grain, such as barley, and also beans and peas, remained entire, of a black color, and offering resistance to pressure. The stones of peaches and apricots are common, thus denoting the frequency of two trees, reputed indigenous in Armenia and Persia. But, what is still more singular, a loaf, stamped with the baker's name in Roman characters, was taken from an oven, apparently converted into charcoal. Different parts of plants prepared for pharmacy, were obtained from the dwellings of those who had been apothecaries. After so great a lapse of time, liquids have been found approaching a fluid state, an instance of which is a phial of oil, conceived to be that of olives. It is white, greasy to the touch, and emits the smell of rancid oil. An earthen vase was found in the cellars containing wine, which now resembles a lump of porous, dark violet-colored glass. The ancients speak of very thick wines requiring dilution previous to use, which would keep two hundred years, and would then acquire the consistence of honey. Solid pitch was also found at the bottom of a vessel, wherein it had probably melted, as it afterwards did from heat in the museum at Portici, which stands near the entrance to the subterraneous city.

An entire set of kitchen furniture has been collected, which displays several utensils exactly similar to those which are now employed. The copper pans, instead of being tinned, are internally coated with silver. These have not been attacked by verdigris. Here is a large brass caldron, three feet in diameter, and fourteen inches deep; an urn or boiler for hot water, similar to those on our tables, having a cylinder in the centre for a heater. There are pestles and mortars, and all kinds of implements for cutting out and figuring pastry, and, in short, a complete culinary apparatus. Utensils of finer quality are likewise collected which had been employed at tables, as

silver goblets and vases, silver spoons, and the remnants of knives.

Various articles belonging to personal ornament and decoration have also occurred. Two silver bodkins are preserved with which they pinned up their hair, eight inches in length, the end of one sculptured with a Venus adjusting her tresses before a looking-glass held by Cupid. Gold ornaments, bracelets, necklaces, with pieces of plate gold suspended to them as lockets, are among the things recovered. Small nets are also found with fine meshes, which some have supposed were employed by ladies to tie up their hair, and others of coarser texture, which must have been used for other purposes. Pieces of cloth, colored red on one side and black on the other, were found on the breast of a skeleton; the texture of which, whether silk, woollen, linen, or cotton, antiquaries have not been able to decide. Very few jewels are discovered, which favors the idea of the inhabitants having had time to escape. A wooden comb was found with teeth on both sides, closer on one side than on the other, and portions of gold lace fabricated from the pure metal. Sandals of laced cord are seen, though it is more commonly believed that leather was in general use among the Italians. A folding parasol, similar in construction to what we esteem a modern invention, was likewise discovered.

There is kept in the museum a case of surgeons' instruments complete, with pincers, spatulæ and probes; also a box supposed to have contained unguents, and pieces of marbles employed in braying pharmaceutical substances. A variety of carpenters' and masons' tools, as chisels, compasses, and trowels, were found, resembling our own; also bolts and nails, all of bronze.

The weights and measures of the ancients have excited considerable discussion, which those preserved in Herculaneum may elucidate. Different balances appear, of which the most common is analogous to the Roman steelyard; but there are some like our common scales, though wanting the needle at top. The weights are either of marble or metal, of all gradations up to thirty pounds. From the marks exhibited by a set of these well made of black

marble, in a spherical shape, it is supposed the pound was divided into eight parts. A weight is inscribed *eme* on one side, and *habebis* on the other. There are pocket long measures, folding up like our common foot rule. Neat copper vases are supposed to have been measures for grain; the capacity of one of these is one hundred and ninety-one cubic inches.

The various implements for writing have repeatedly been found. That the Romans were acquainted with the art of making glass is proved by the varieties discovered in these exfodiations. Considerable numbers of phials and bottles, chiefly of an elongated shape, are preserved; they are of unequal thickness, much heavier than glass of ordinary manufacture, and of a green color. Vessels of cut white glass have been found, and also white plate glass, which antiquaries suppose was used in lining chambers called *cameræ vitreæ*. Colored glass or artificial gems, engraved, frequently occur; and the paintings exhibit crystal vessels.

The beauty and variety of the vases have attracted particular notice. There is one preserved, which is four feet in diameter, of fine white marble; others are of earthenware or silver, and the majority of bronze or copper; some are low, wide and flat; others tall and narrow, plain, fluted or sculptured. Sacrificial vases were supported on tripods, whose construction seems to have been attended with equal care. Some of the latter are richly sculptured with real and imaginary figures of men and animals. Several tripods are very ingeniously constructed, so that the feet may be closed or expanded by double sets of hinges. Endless diversity and infinite elegance are displayed in the lamps, but few chandeliers have been discovered. Sometimes a lamp appears as a shell, then as a bird; sometimes as a human figure, or as a quadruped. The vases, lamps, and tripods were particularly used in sacrifices, several of which are represented in the pictures; and among others are sacrifices to the Egyptian deities. There were many funeral urns and sepulchral lamps, such as those regarding which vague ideas have been entertained, as formed for containing perpetual fire.

In regard to sports and pastimes, numerous remains render us familiar with those of the ancient Romans. Here we find dice like those now used, with the same disposal of points on a cube; and dice-boxes of bone or ivory, besides some of a flattish shape. Several are false, being loaded on one side; and the manner of throwing the dice appears on a picture. No musical instruments are found except the sistrum, which we imperfectly understand, cymbals, and flutes of bone or ivory. However, a concert is represented on a picture sixteen inches square, containing a lyrist, a player on a double flute, probably by a mouth-piece, and a female apparently singing from a leaf of music, besides two other figures.

Various theatrical masks, of different fashions, have been found in clay and metal along with moulds for their formation. Their use in dramatic representations is well known, and is the subject of many of the pictures. The theatre was a favorite resort of the ancients; and some ivory tickets of admission, with the author's name and that of the piece, are preserved from Herculaneum. Rope-dancing is exhibited in pictures, wherein all the modern dexterity of playing on musical instruments, pouring out liquids into cups, and other feats of address are shown. The most elegant and graceful of the Herculanean pictures, are perhaps those of female dancers.

It is to be observed in general, that the quality of the statues infinitely exceeds that of the pictures; and that the vases, tripods, lamps, and candelabras are frequently of the finest workmanship. Of many, once complete, only fragments remain; and while gold, silver, bronze, or clay remain entire, iron has altogether wasted away.

ARTS OF THE CHINESE.

The Chinese have existed as a nation from a period of indefinite antiquity. Although, from the absence of free communication with civilized countries, this people have hardly risen above a semi-barbarous state, yet, by processes of their own, they seem to have arrived at a knowledge of most of the common arts of civilized life, and have

also even taken precedence of the Europeans in some branches of manufacture.

The most stupendous ancient work of this country is the great wall of China, that divides it from northern Tartary. This astonishing fabric extends, for the distance of one thousand five hundred miles, over the summits of mountains nearly a mile in height, and across deep valleys and wide rivers, by means of arches. In many places it is doubled or trebled to command important passes; and at the distance of every hundred yards is erected a tower or massive bastion. The foundations and angles are built of a strong gray granite, but the materials for the greater part consist of bluish bricks. The mortar is remarkably pure and white. In some parts, where less danger was to be apprehended, the wall is not equally strong or complete, and towards the northwest it consists merely of a strong rampart of earth. At one place, it is twenty-five feet high, and at the top about fifteen feet thick. Some of the towers, which are square, are forty-eight feet high, and about forty feet in width. It has been calculated that, with the same materials, a wall one foot in thickness and twenty-three in height might be carried twice round the whole globe. The time of the erection of this great barrier has not been satisfactorily ascertained. It is believed to have existed for two thousand years, but some writers allow to it a much less degree of antiquity.

The great canal of China is one of the wonders of art. It runs from the city of Canton to Pekin, a distance of eight hundred and twenty-five miles. It is about fifty feet wide, passes through or near forty-one large cities, and has seventy-five large feeders to keep up the water, besides several thousand bridges. In the southern provinces of China, is the grandest inland navigation in the known world, one of the canals being one thousand feet wide, having its sides built with massy blocks of gray marble and granite. This immense aqueduct is raised several feet above the surface of the country, and flows with a current of about three miles an hour.

The Chinese buildings are more striking from their extent than from their taste or magnificence. The impe-

rial palace at Pekin may be compared to a large city. The Porcelain Tower of Nankin is a remarkable structure, which derives its name from its covering of china tiles beautifully painted. It is variously estimated at from three to seven hundred years old.

The Chinese lay claim to the invention and use of the mariner's compass, of gunpowder, and of paper, which are thought by some to have been manufactured by them earlier than the periods when they were first known in Europe. They preceded the Europeans in the manufacture of fine porcelain, of japan ware, and of paper-hangings, and are still said to excel other nations in the character of their fireworks. They were acquainted with the art of printing with blocks at a remote period of antiquity.

The materials employed by the Chinese at this day, are generally derived from their own country. An article for candles is made from the tallow tree. All the common metals, except platinum, are found in China, and employed in the arts. Some of the mountains produce marble and crystal.

The Chinese appear to have been indebted to themselves alone for the invention of their tools. They succeed in casting bells of immense size, some of which are said to weigh one hundred and twenty thousand pounds. Their gold and silver are not coined, but cut into pieces and weighed in scales of extreme nicety. The cutting of ivory is carried to a high degree of perfection, and toys and trinkets are made with great delicacy out of various materials.

Among those articles which are the joint product of agriculture and manufactures, we may mention silks, linen, and cotton as having been known among them for an indefinite length of time. Tea, which seems to require a peculiar climate for its growth, and a peculiar manipulation for its drying, rolling, and packing, is a product hitherto almost exclusively monopolized by the Chinese and their neighbors of Japan. The attention of some other nations is but just beginning to be directed to the production of this article.

ARTS OF THE ARABIANS.

The sterile character of the Arabian desert, and the wandering life which from time immemorial has been led by its inhabitants, have given to this people a peculiar nationality of character, both in ancient and modern times. They have at all times been difficult of subjugation, and have seldom accumulated either wealth or works of industry sufficient to tempt the cupidity of invaders. Nevertheless, in some parts of this country, and especially in Arabia Petræa, there are ruins of ancient works, which bespeak the former existence of art and power. Near the village of Wadi Moosa are the relics of ancient Petra, formerly the capital of Arabia Petræa. This city in the reign of Augustus Cæsar was a place of consequence, and the residence of a monarch of the country. It was afterwards conquered by Trajan, and still later by Baldwin, King of Jerusalem. There now remain, upon the sides of a deep chasm or pass in the mountains, a number of remarkable structures, resembling fronts of temples, executed somewhat in the style of the later Roman architecture, and carved out of a solid rock. A statue of Victory with wings, and groups of colossal figures, adorn the summit of the principal temple. On all sides the rocks are hollowed into chambers and sepulchres, and an amphitheatre is excavated at one end of the mountain.

The ruins of Jerasseh are said by Mr. Bankes and other travellers to equal those of Palmyra in magnitude and beauty. A grand colonnade runs from the eastern to the western gate of the city, formed on both sides of marble columns of the Corinthian order, and terminating in a semicircle of sixty pillars of the Ionic order, and succeeded by another colonnade running north and south. At the western end is a theatre, the proscenium of which remains entire. There are two amphitheatres of marble, and three splendid temples, besides numerous ruins of columns, statues, and inscriptions.

During the early part of the dark ages, the Arabians cultivated some of the arts and sciences, especially astronomy, chemistry, and medicine. They introduced

various chemical processes, and were acquainted with distillation and sublimation, arts which are supposed to have been hardly known to the Romans. They also introduced many of the important drugs and spices of the East, which afterwards passed through their hands into Europe. The magnifying power of convex lenses was known to Alhazen, an Arabian philosopher, who flourished about the year 1100.

ARTS OF THE MIDDLE AGES.

In the period emphatically denominated the *dark ages*, extending from about the fifth to the twelfth century, the whole world seems to have relapsed into barbarism, and the arts and sciences, previously cultivated with much success, fell into a retrograde course, from which they were scarcely recalled, during a thousand years. The incessant prevalence of devastating wars, the insecurity of property, the oppressive exactions of the powerful, and the wretched destitution and servitude of the poor, placed an effectual barrier in the way of all successful efforts of ingenuity and enterprise. Few monuments remain, that exhibit the smallest progress in art during many centuries, while, on the other hand, some of the finest buildings of antiquity were dilapidated, or their walls disfigured with numberless perforations, in search of treasures supposed to be hidden, or even to obtain the bronze or iron cramps with which the stones were united.

At length, the power of the Saracens in Africa and Spain, and of various Christian monarchies in Europe, gave sufficient stability to their governments, to enable them to furnish some encouragement to the arts. The courts of powerful princes became the resort of ingenious men, and the convenience, safety, and even luxury of a portion of mankind began again to be objects of attention. Architecture revived, but under forms wholly unknown to the ancients. The Saracenic architecture of the Moors and Turks, and the Gothic architecture of Christian Europe, took their rise in the middle ages.

We look in vain through the chronological events of a long period in the middle ages, to discover records of any

important advances made in useful knowledge, beyond the stock which was previously in possession of the ancients. A few insulated notices inform us of the rude beginnings of certain arts, which afterwards rose into importance and exerted a decisive influence on the condition and progress of mankind.

The invention of *gunpowder* took place about the thirteenth or fourteenth century. It appears that Friar Bacon, who died in 1294, was acquainted with a composition of "saltpetre, and other ingredients," which had the properties of gunpowder. A German monk by the name of Schwartz is by some supposed to be the inventor, about the year 1320. The Chinese claim the invention and use of gunpowder at a much earlier period. It was used by the Venetians in a war with the Genoese, in 1380. Artillery is supposed to have been employed by the English at the battle of Crecy. Muskets and pistols were not introduced till the beginning of the sixteenth century.

The *mariner's compass* is supposed to have been invented by John de Gioja, a Neapolitan of Amalfi, about the end of the thirteenth century. Other accounts say that it was brought to Europe from the East, as early as the year 1260. The attractive property of the magnet for iron had been known from remote antiquity, but its polarity appears not to have been known in Europe till the period before mentioned.

Clocks moved by weights, according to Professor Beckmann, began to be used in the monasteries of Europe in the eleventh century. They are supposed to have been an invention of the Saracens. As early as 807, a clock was sent to Charlemagne by the Caliph Haroun Alraschid, which struck the hours, but it is supposed to have been constructed on the principle of the ancient clepsydra. Clocks are spoken of by writers of the thirteenth century as being then well known.

Certain *optical instruments* appear to have come into use in the middle ages. Roger Bacon, already alluded to, was acquainted with the power of convex and concave lenses to magnify and diminish the image of objects; and

treatises on optical subjects were written by Alhazen, at an earlier period. The telescope was not invented till the end of the sixteenth century.

ARTS OF MODERN TIMES.

In contemplating the changes produced in the condition of society by the inventions and discoveries of modern times, a field of vast extent is opened to our view. In conjunction with the great moral and political causes which have been operating with increasing influence since about the fourteenth century, the arts have unquestionably afforded a means, without which society could never have become what we see it at the present day.

It is difficult to select, from among the triumphs of modern art, those subjects which ought to receive our first attention. The introduction, which has already been noticed, of the compass into navigation, and of gunpowder into military operations, has effected, in both these fields of human enterprise, an entire revolution. But the *art of printing*, which soon followed, has surpassed both these in the importance of its results, and may be considered as having afforded the real basis of modern civilization and intelligence. Printing was introduced at Haerlem and Mentz, about the middle of the fifteenth century, and the names usually associated with its invention are those of Coster, Guttenburg, and Faust. An historical sketch of this art will be found under its appropriate head.

With the dissemination and increase of intelligence, there arose a greater respect for order, and for the right of property. As the stability of society increased, a greater taste grew up for the refinements of social life, and the cultivation of domestic comfort. Improvements arose in domestic architecture, and in the customs connected with clothing, furniture, and food.

Chimneys, which were unknown to the ancients, were introduced in some parts of Italy in the beginning of the fourteenth century. In England, previously to the reign of Elizabeth, there were no chimneys in a greater part of the houses. " The fire was kindled against the wall, and the smoke found its way out, as well as it could, by

the roof, the door, or the windows. The houses were mostly built of wattling plastered over with clay; the floors were of earth, strewed, in families of distinction, with rushes, and the beds were only straw pallets with a log of wood for a pillow."*

Glass windows, although known to the ancients, as appears by some of the remains at Pompeii, were far from being in general use. Beckmann says that they did not begin to be used in England in private houses until nearly a century after the Norman conquest, and even then, they were considered as marks of great magnificence. The manufacture of glass in England commenced about the middle of the sixteenth century, and that of window-glass at a considerably later time.

Riding carriages were used for convenience and amusement by the ancients, but disappeared during the dark ages, and were not again revived until the restoration of arts and letters in modern times. Riding on horseback was for many centuries resorted to, by persons of the highest rank, of both sexes, and the use of carriages was deemed effeminate and disreputable. In 1550 there were but three coaches in Paris, one belonging to the Queen, another to Diana de Poictiers, the king's mistress, and a third to René de Laval, a nobleman, who, from extreme corpulency, was unable to ride on horseback. Carriages for hire, on the plan of our hackney-coaches, were first introduced in London in the year 1625. The establishment of stage-coaches followed some time afterwards, and there is extant an old advertisement of a stage-coach which ran on regular days from London to York, performing the journey, of two hundred miles, in four days.

Pavements of streets were in use among the ancients, as appears from the remains at Rome, Pompeii, &c. But in modern cities they were slowly introduced. The streets of London were not paved till the eleventh century, nor those of Paris till the twelfth, and the general introduction of this improvement is of much later date.

Painting in oil, at least in its nicer applications, appears to be a modern art. It was first applied to the

* Beckmann's History of Inventions.

execution of designs and figures by John Van Eyck, in Flanders, about the year 1410.

The art of *engraving* on wood or metal, with a view to printing the design on paper, is exclusively a modern invention. Wood-engraving is supposed to have originated in the latter part of the thirteenth century; one of the earliest specimens extent, is by Alessandro Curio, bearing the date of 1423. Engraving on metal appears to have been practised a few years afterwards. Its invention is ascribed by the Italians to Finsguerra, a goldsmith of Florence, and by the Germans to Schoengaur, a citizen of Antwerp. Mezzotinto engraving was introduced by Prince Rupert, in 1649.

Optical instruments are mostly of modern invention. It is uncertain at what time spectacles were first introduced; but it appears that Roger Bacon had some knowledge of the use of the convex lens in assisting the sight of old people. This remarkable person had also a crude idea of the telescope, which instrument was practically invented by Jansen, a Dutch spectacle-maker, in the latter part of the sixteenth century, whose attention was turned to the subject by the accident of a child placing together a concave and convex lens at a certain distance from each other, by which arrangement a magnified view of distant objects was produced. The telescope was afterwards reinvented by Galileo, in 1609. The camera obscura was invented by John Baptista Porta, a little before this time.

Watches are said to have been first made by Peter Hele, in 1510. Previously to this invention, clocks moved by weights had been known for a long time. To render these timekeepers portable, a spring was substituted for a weight, and the first watches were called *Nuremberg eggs*, from the place of their manufacture. The invention of the spring balance is claimed for Dr. Hooke in England, and for Huygens on the continent.

Paper made of cotton is supposed to have been inventted as early as the tenth century, and had become more common than parchment in the twelfth. Some authors attribute the invention to the Chinese, at a more remote

period. But paper made in the modern way, from linen rags, was not manufactured in Europe till about the fourteenth century, and the first paper-mill was established in 1390, at Nuremberg in Germany. The first English paper-mill was erected in the reign of Queen Elizabeth, but failed for want of support, and the paper used in England as late as the beginning of the last century was imported from France and Holland.

The earliest newspaper was published in the reign of Queen Elizabeth, in 1588, and was entitled, 'The English Mercurie, published by authoritie, for the contradiction of false reports.'

The *spinning* of *cotton* by machinery has given birth to one of the greatest revolutions of modern times, in the direction of human industry. The use of the cotton plant has been known from an early period; it was introduced from the East by the way of Malta, and continued to be spun and woven by hand, both in Asia and Europe. In the year 1767, Mr. James Hargreaves, a weaver in Lancashire, contrived a machine by which many threads could be spun at once, and for which he obtained a patent under the name of the "spinning jenny." It was wrought by hand, and one person could spin with it eighty-four threads at once. This invention was succeeded by that of Sir Richard Arkwright, whose two patents were dated 1769 and 1775. He was the inventor of the "water spinning frame," and, after struggling with many difficulties and much opposition, lived to see the complete establishment of the cotton manufacture, and to realize a large fortune from its results.

Calicoes are supposed to have been manufactured among the oriental nations in the time of Alexander the Great. But they were probably executed by drawing rather than printing. Calicoes were introduced into England in 1631, deriving their name from the city of Calicut in India. The manufacture was set up in London in 1676. Printing by cylinders came into use in the present century.

Hats made of felt and fur are a modern invention. They are said to have been invented in Paris, by a Swiss,

in the beginning of the fifteenth century. Before this period caps, hoods, and helmets, of various forms, occupied their place; and some of the most civilized nations, such as the Romans, went bare-headed, except on particular occasions. King Charles VII. made his triumphal entry into Rouen in 1492 wearing a hat. The manufacture of felt hats was begun in England in the time of Henry VIII.

Various operations in the manufacture of the *metals* have had their origin in modern times. Among these may be mentioned that of wire-drawing, for, although wire was known to the ancients, it was probably made by a difficult process. Mechanics known by the name of "wire-drawers" existed at Augsburg in 1351. In England wire was manufactured by hand until 1565, when the art of drawing it with mills was introduced by some foreigners. In general, it is safe to state, that all those important operations in which manufactures in metal are made upon a large scale by machinery, are the result of modern improvement. With these we must include articles of use and convenience which were not employed by the ancients; among which may be mentioned fire-arms, the manufacture of which followed the invention of gunpowder; and also another very different article, table-forks, the use of which was introduced in England about two hundred and fifty years ago, previously to which time people were accustomed to eat at table with their fingers.

Aerostation, or the art of ascending into the atmosphere by means of balloons, was invented in France, by the Messrs. Montgolfier, in 1783. The first balloons were inflated with common air rarefied by heat, and in a machine of this description M. Pilatre de Rozier made the first ascension. This attempt was completely successful, though the unfortunate aeronaut lost his life in a subsequent attempt, in consequence of his balloon taking fire when at a great height. Balloons inflated with hydrogen were introduced at Paris in the same year. The parachute had been known, and used upon a small scale, by jugglers in India, for more than a century. M. Garnerin descended in one of these from a balloon, at Paris, in 1797.

Diving-bells are of modern origin. The first information respecting them is from an author named Taisnier, who relates, that at Toledo in Spain, in the year 1538, he saw, in the presence of the Emperor Charles V. and about ten thousand spectators, two Greeks let themselves down under water in a large inverted kettle, with a light, and rise up again without being wet.

The *Steam-engine* may be justly considered as the greatest triumph which has been achieved by modern genius and perseverance. The following are some of the most interesting facts in its history.

The ancient Greeks and Romans appear to have been acquainted with the power of steam to produce motion, and invented the eolipile, which was a close vessel containing water, and which gave out a forcible current of steam whenever the water was heated. The force of this current was used by Hero to produce a revolving motion.

The power of confined steam, acting by its pressure, was discovered by the Marquis of Worcester, and an account of its effect published by him in 1663. He produced a steam-power sufficient to burst a cannon, and constructed a machine capable of raising water to the height of forty feet. He has not, however, left any drawings or particular description of his machine.

In 1698, a patent was granted to Thomas Savery, for a method of raising water by steam. This apparatus consisted of a boiler, a separate steam-vessel, and pipes commanded by valves. The steam from the boiler was first admitted so as to fill the steam-vessel. It was then condensed, and the steam-vessel filled with water, which rose by the atmospheric pressure from the well or mine. The steam was then readmitted, and the water in the vessel was driven upward to the top of the pipes, and discharged.

About the year 1705, Thomas Newcomen constructed a working steam-engine, which has since been called the *atmospheric* engine. It contained a cylinder and piston, and an alternating beam, which was applied to raise water by working a pump. The steam was condensed in

the cylinder itself, and the valves were moved by the hand, until an attendant contrived to make the machine move its own valves, by attaching strings to the working-beam.

After this the steam-engine continued without any important alteration for more than half a century, when, about 1769, the discoveries and inventions of James Watt gave a new spring to the energies of this machine, and more than doubled the power which it had formerly possessed. Mr. Watt's improvements were numerous and important, but those of greatest value were the following. 1. He introduced the separate condenser. 2. He applied the double action of steam, by closing the top of the cylinder, and admitting the steam alternately at each end. 3. He converted to use the expansive power of steam, by cutting off the current before the end of the stroke. Mr. Watt also invented the principle of the parallel motion, and applied the governor, to regulate the supply of steam.

In 1802, the first *high-pressure* or *non-condensing* engines were constructed by Oliver Evans, in Philadelphia, and in the same year by Trevithick and Vivian, in England. The idea of such an engine had before occurred to Leopold, Watt, and others. The first steam-carriage was put in motion on a rail-way, by Trevithick and Vivian, in 1805.

Steam navigation was suggested in England by Jonathan Hulls, in 1736. It was first tried in practice by the Marquis de Jouffroy, in France, in 1782, and nearly at the same time in America, by James Rumsey of Virginia, and John Fitch of Philadelphia. It was first made practically successful by Robert Fulton, at New York, in 1807. The first steam-vessel which crossed the Atlantic, was the American ship Savannah, in 1819. The Sirius and Great Western, which were the first steam-ships in the present successful lines, arrived at New York from England in April, 1838.

ARTS OF THE NINETEENTH CENTURY.

Nothing more fully exemplifies the fertility of human invention, than the fact that scarcely any year passes by

without the discovery or improvement of some branch of useful industry. It would be natural to suppose that after the ingenuity of mankind had been devoted for so many centuries to the combination and application of materials, the field of new experiment would become exhausted, and that improvements would at length cease to appear. But experience has proved that the opposite state of events continually occurs. Since about the beginning of the present century and within the lives of many who are now upon the stage, some of the most important revolutions have taken place in the customs of society, derived entirely from innovations in the arts. These will be spoken of in their appropriate places. At present, it is sufficient to adduce as examples the practical introduction of steamboats and rail-roads, gas lights and Argand lamps, stereotyping and machine printing, lithography and steel-engraving, McAdam roads and wooden pavements, the heating of dwelling-houses by steam, water and hot air, the extended use of India rubber, the practical improvements in the arts dependant on chemistry, and the boundless introduction of labor-saving machinery into every department of mechanical manufacture. The causes of these vast and increasing strides in the improvement of the physical condition of society, are to be sought for in the advanced state of the natural sciences, the increased diffusion of knowledge, order, and morality, and also in the state of general peace, which for a quarter of a century has existed among the principal civilized nations of the globe.

Works of Reference.—Beckmann's History of Inventions, 3 vols. 8vo. ;— Fosbrooke's Encyclopedia of Antiquities, 3 vols. 4to, 1825, &c. ;— Wilkinson's Manners and Customs of the Ancient Egyptians, 3 vols. 8vo. 1838 ;—Elmes' Lectures on Architecture, and Dictionary of the Fine Arts ;—Lardner's Treatise on Arts and Manufactures of the Romans, 12mo. in Cabinet Cyclopedia ;—Ure's Dictionary of Arts and Manufactures, 8vo. 1839.

CHAPTER II.

OF THE MATERIALS USED IN THE ARTS.

MATERIALS FROM THE MINERAL KINGDOM. — *Stones and Earths.*—Marble, Granite, Sienite, Freestone, Slate, Mica, Mica Slate, Soapstone, Serpentine, Gypsum, Alabaster, Chalk, Fluor Spar, Flint, Porphyry, Buhrstone, Novaculite, Precious Stones, Emery, Sand, Pumice, Tufa, Peperino, Tripoli, Clay; Asbestos. *Cements.*—Limestone, Puzzolana, Tarras, Other Cements, Maltha. *Metals.*—Iron, Copper, Lead, Tin, Mercury, Gold, Silver, Platinum, Palladium, Zinc, Nickel, Antimony, Cobalt, Bismuth, Arsenic, Manganese. *Combustibles,* &c.—Bitumen, Amber, Coal, Anthracite, Graphite, Peat, Sulphur. MATERIALS FROM THE VEGETABLE KINGDOM.—Wood, Bark, Oak, Hickory, Ash, Elm, Locust, Wild Cherry, Chestnut, Beech, Basswood, Tulip Tree, Maple, Birch, Buttonwood, Persimmon, Black Walnut, Tupelo, Pine, Spruce, Hemlock, White Cedar, Cypress, Larch, Arbor Vitæ, Red Cedar, Willow, Mahogany, Teak Wood, Lance Wood, Boxwood, Lignum Vitæ, Cork, Hemp, Flax, Aloes, Pine Apple, Manilla Hemp, New Zealand Flax, Cotton, Straw, Palm Leaves, Turpentine, Caoutchouc, Oils, Resins, Starch, Gum. MATERIALS FROM THE ANIMAL KINGDOM.—Skins, Hair and Fur, Quills and Feathers, Wool, Silk, Bone and Ivory, Shell, Horn, Tortoise Shell, Whalebone, Glue, Oil, Wax, Phosphorus.

THE mineral, vegetable, and animal kingdoms, respectively contribute to supply the substances which are necessary in the arts. Of these substances, many have been known and used from the time of the earliest records; others are of recent introduction, and additions are still making to the stock previously known. The value of a substance to the arts, may be estimated from the importance of the object it fulfils, its durability, the number of purposes to which it may be applied, and the facility with which it is convertible to use.

MATERIALS FROM THE MINERAL KINGDOM.

STONES AND EARTHS.——*Marble.*—The class of stones denominated *calcareous*, is exceedingly numerous and abundant in nature. Of these, marble is the most

important. It is a granular carbonate of lime, varying in color, texture, and hardness Marble is extensively used for building, statuary, decorations, and inscriptions. In warm countries, it is one of the most durable of substances, as is proved by the edifices of Athens, which have retained their polish for more than two thousand years. Severe frost, preceded by moisture, causes it to crack and scale. Great heat reduces it to quicklime. Marble is wrought by chiselling, and by sawing with smooth plates of iron, with sand and water. It is polished by rubbing with sand and water, and afterwards with putty and soft substances.

Numerous stones of the calcareous class, more or less approaching to marble in their character, have been converted to use in different countries. The pyramids of Egypt are built of a grayish white calcareous stone, enclosing shells. The Parthenon, and other structures of Athens, are of Pentelic marble, distinguished by slight greenish veins. The mosques of Constantinople are of a fine-grained limestone from Pappenheim, the same which is now used in lithography. At Rome, a porous whitish limestone, called *tophus* by the ancients, and *travertino* by the moderns, is the material of the Colosseum, of St. Peter's church, &c. The ruins of Pæstum are of a stone nearly similar. The building called the Tomb of Theodoric, at Ravenna, has a dome consisting of a single stone, which is thirty-four feet in diameter. It is a gray limestone from Istria, and is computed to have weighed, when taken from the quarry, more than two million pounds. Paris is built with calcareous stone, of which there are five kinds. The Portland stone, of which St. Paul's and other edifices in London are constructed, is a calcareous rock called *Oolite* by mineralogists. Specimens of marble abound in the United States, and are seen in the City Hall of New York, the United States and Pennsylvania Banks, Philadelphia, the Washington Monument, Baltimore, &c. The columns of the Girard college, in Philadelphia, were obtained from the quarries in Sheffield, Berkshire county, Massachusetts.

In statuary, the Venus de Medicis, and Diana venatrix, are formed of Parian marble. The Apollo de Belvidere, according to Dolomieu, is made of Luni marble ; and if so, must be posterior to the time of Julius Cæsar, before which period that quarry was not opened.

Granite.—Granite is apparently the oldest and the deepest of rocks. It is one of the hardest and most durable which have been wrought, and is obtained in larger pieces than any other rock. Granite is a compound stone, varying in color and coarseness. It consists of three constituent parts ; viz., *quartz*, the material of rock crystal ; *feldspar*, which gives its colors, and which is the material of porcelain earth ; and lastly *mica*, a transparent, thin, or foliated substance, which affords a flexible substitute for glass, when obtained in large pieces. Granite is chiefly used for building. It is split from the quarries by rows of iron wedges driven simultaneously in the direction of the intended fissure. This method is thought by Brard to have been known to the ancient Romans and Egyptians. The blocks are afterwards hewn to a plane surface by strokes of a sharp-edged hammer. Granite is also chiselled into capitals and decorative objects ; but this operation is difficult, owing to its hardness and brittleness. It is polished by long-continued friction, with sand and emery.

The largest mass of granite, known to have been transported in modern times, is the pedestal of the equestrian statue of Peter the Great, at St. Petersburgh. It is computed to weigh three million pounds, and was transported nine leagues by rolling it on cannon balls. Those of cast iron being crushed, others of bronze were substituted. Sixty granite columns at St. Petersburgh consist each of a single stone twenty feet high. The columns in the portico of the Pantheon at Rome, which are thirty-six feet eight inches high, are also of granite. The shaft of Pompey's Pillar, so called,* in Egypt, is sixty-three feet in height, and of a single piece. It is

* The inscription on this pillar is said by the Earl of Mountnorris, in Brande's Journal, to belong to Dioclesian, and not to Pompey, as was formerly supposed.

said to be of red granite, but is possibly sienite. In the eastern part of the United States, a beautiful white granite is found in various places, and is now introduced in building. The new market-house in Boston, the United States Bank, &c., are made of it.

Sienite.—This rock is related to granite, and resembles it in its general characters. It consists chiefly of feldspar and hornblende. Sienite is obtained in large pieces, and possesses all the valuable properties of granite; but being harder, it is somewhat more difficult to chisel. It is found in Egypt, and constitutes the material of many of the obelisks. The Romans imported it from that country. Sienite is found abundantly near Boston, and is introduced into many structures. The Washington Bank, the Court-house, the Bunker Hill Monument, and the Astor House in New York, consist entirely of this stone. Its extreme hardness renders it one of the best materials for McAdam roads. A railway is built at Quincy for transporting the stone from the quarry to the sea, and the name of *Quincy stone* is now commonly applied to it.

Freestone.—Freestone consists of sand, or silicious particles, united by a cement. It is also called *sandstone.* It varies in color, from grayish white to red and dark brown. It is of moderate hardness, in general, and easily wrought by the chisel. Varieties of freestone are used in building, in different parts of Europe. In Africa, the temple of Hermopolis is composed of enormous masses of this stone. In America, the Capitol, at Washington is of the Potomac freestone, likewise the façade of St. Paul's church, in Boston. This stone is used for various other practical purposes, particularly the grinding of steel instruments, and the filtering of water.

Slate.—Slates are valuable for the property of splitting in one direction, so as to afford large fragments which are perfectly flat and thin. The best slates are those which are even, compact, and sonorous; and which absorb the least water on being immersed. Slates are much used as an incombustible covering for the roofs of

houses. Tablets, gravestones, and writing slates, are also formed from them.*

Mica.—Mica, which has been already mentioned, is a finely foliated, elastic substance, transparent when obtained in thin layers. It is used for lanterns, and is inserted in the doors of stoves to show the state of the fire. It becomes opaque when exposed to much heat. It is sometimes cut into feathers and other ornaments, and affords a *flexible* substitute for glass.

Mica Slate.—This slate is well known by its brilliant silvery lustre. It splits into tablets, which are obtained of the diameter of eight or ten feet. It is chiefly used for the flagging stones of sidewalks. It is apt to crumble at the corners, and is too friable to bear the attrition of carriage wheels.

Soapstone.—This stone is usually of a grayish color, moderately soft, and having an unctuous feel, which is compared to that of soap. It is remarkable for bearing heat, and sudden changes of temperature, without injury. It receives a tolerable polish. Soapstone, on account of its softness, is wrought with the same tools as wood. It is sometimes used in building, but is not always durable. It is, however, of great importance in the construction of fireplaces and stoves, and is extensively used for this purpose. Slabs of good soapstone, when not exposed to mechanical injury, frequently last eight or ten years, under the influence of a common fire on one side, and of cold air on the other. It grows harder in the fire, but does not readily crack, nor change its dimensions sufficiently to affect its usefulness. Owing to the facility with which it is wrought, its joints may be made sufficiently tight without dependence on cement. Among the best quarries for fire-proof stone, is that of Francestown, New Hampshire. Soapstone is manufactured into various vessels and utensils, and is advantageously em-

* Various artificial compositions have been employed as substitutes for slate, in forming water-proof coverings for roofs. One of these, which appears to have been successfully used in the north of Europe, is formed of bolar earth, chalk, glue, pulp of paper, and linseed oil.—*Franklin Journal*, iv. 89.

ployed for aqueducts. Pumps are sometimes made of it. It is found to be one of the best materials for counteracting friction in machinery, for which purpose it is used in powder mixed with oil. A hard species of soapstone, from Reading, in Massachusetts, has lately been introduced into building.

Serpentine.—Serpentine is a smooth, compact stone, more or less of a greenish color, composed chiefly of magnesia and silex. It is sufficiently soft to be scratched with a knife, and receives a polish like that of marble. It is used in building, in Florence and other parts of Italy, and in Saxony it is wrought into many small articles of ornament.

Gypsum.—Gypsum, called in commerce *plaster of Paris*, is a sulphate of lime, of which there are many varieties. When dried by heat, ground to fine powder, and mixed with water, it has the property of becoming hard in a few minutes, and of receiving accurately the impression of the most delicate moulds. It is extensively employed for *stucco* working, and plastering of rooms. It furnishes a delicate, white, and smooth material for casts of statues, architectural models, impressions of seals, &c. In the art of stereotyping, it is indispensable. It is used in agriculture to fertilize certain soils.

Alabaster.—Under this name, two substances are known in commerce. One is a carbonate of lime, deposited by the dripping of water in stalactitic caves. The other, and the most common, is a compact gypsum. This is softer than marble, translucent, and susceptible of a fine polish. Many beautiful ornaments, such as vases, statues, shades for lights, &c., are made from it. As alabaster of the last species is soluble in five hundred parts of water, Mr. Moore has proposed an easy method of cleansing it, by immersing it for about ten minutes in water, and afterwards rubbing it with a brush dipped in dry, powdered plaster.

Chalk.—Chalk is a soft carbonate of lime, the properties of which are well known. It is used as the basis of various white pigments, and cementing substances. Common *whiting* is purified chalk, prepared by reducing the

chalk to fine powder and agitating it with water. The sand and coarser particles first subside, after which the water is drawn off and the whiting suffered to deposit itself. Chalk, by calcination, furnishes excellent lime.

Fluor Spar.—This is a fluate of lime. The variety chiefly used is the Derbyshire spar, which is beautifully variegated with purple and other colors. Ornamental objects and utensils are made from it. Its acid, when disengaged, is sometimes used to corrode glass.

Flint.—Flint is found in roundish masses, and is composed almost wholly of silex. Its extreme hardness causes it to strike fire readily with steel, from which property its greatest use is derived. Gun-flints are formed by practised workmen, who break them out with a hammer, a roller, and steel chisel, with small repeated blows. Flints are used also in the manufactures of glass, porcelain, and Wedgewood's ware. For this purpose, they are reduced to fine powder by heating red hot, and plunging them in water; afterwards by pounding, sifting, and washing. Flints are broken up to form McAdam roads.

Porphyry.—Porphyry is a variegated stone, consisting of small crystals of feldspar or quartz, imbedded in a basis of a darker color. It receives a beautiful polish, but its extreme hardness renders it difficult to work. The ancients made columns and even statues of this material; but the moderns confine its use chiefly to smaller works, such as vases, boxes, mortars, &c.

Buhrstone.—This is a hard, silicious stone, remarkable for its cellular structure; containing always a greater or less number of irregular cavities. Hence its surface, however worn and levelled, is always rough. This property renders buhrstone an invaluable material for mill-stones. When it is not found of sufficient size for this use, small pieces of it are fitted together, cemented, and bound with an iron hoop. It is imported from France, and is also found in some localities in the United States.

Novaculite.—This stone is commonly known under the names of *hone*, Turkey oilstone, &c. It is of a slaty structure, and owes its power of whetting or sharpening steel instruments, to the fine silicious particles

which it contains. Various other stones are used as whetstones, such as common slate, mica slate, freestone, &c.

Precious Stones.—These are better known as objects of luxury, than of use; yet their preparation gives rise to an extensive branch of industry. They are in general distinguished for their small size, and great brilliancy, permanency, and hardness. The latter quality renders them useful in the arts. The diamond is generally employed for cutting sheets of glass. The diamond, ruby, sapphire, and some others, are used by watchmakers for pivot holes to diminish the friction of their verges and axles. These stones are wrought by grinding them with emery and other hard powders. The diamond can only be cut with its own dust. Various hard, silicious stones of less value, as the carnelian, jasper, agate, &c., are used by lapidaries for engraving seals, cameos, and other objects of ornament.

Emery.—The best emery is a variety of the corundum stone, obtained chiefly from the island of Naxos, in the Archipelago. Several other substances, however, are sold under this name. Emery is the hardest of all known substances, except the diamond, and its powder is extensively used in grinding and polishing metals, stones, and glass. It is reduced to powder by grinding it in a steel mill, and is afterwards assorted into parcels of different fineness, by agitating it with water, and separating the particles which deposit themselves at different times; the finest articles being the last which subside.

Sand.—Sand of the best quality, is that which consists of particles of pure quartz, and such only is used in the manufacture of fine glass. It is found in various localities; but is most commonly procured, in this country, from the banks of the Delaware. Impure sand answers only for bottles and inferior glass. For mechanical purposes, such as grinding glass and marble, sharp sand, the particles of which are angular, is best. The sand used for moulds, by brass-founders, possesses a somewhat argillaceous character, sufficient to render it moderately cohesive when wet, in consequence of which quality it

retains its shape. The sand used in mortar should be sharp, and free from all perishable or deliquescent ingredients.

Pumice.—This is a spongy, porous stone, of a fibrous texture, and so light as often to swim in water. It is considered to be of volcanic origin. It is employed to grind the surface of metals, and other minerals. On account of its lightness, it is sometimes used to construct domes, vaults, and other elevated parts of buildings. The dome of the mosque of St. Sophia, at Constantinople, is said to be of this material.

Tufa.—This name is applied to a number of volcanic productions, some of which are aggregates of sand, ashes, and fragments of scoria and lava, united by a cement. The tufa which is found about Rome, is of a reddish color, and is supposed to be the *lapides rubri* of Vitruvius. Its surface is easily decomposed by the atmosphere, yet some of the ancient Roman temples and aqueducts are built of it, and among others, the temple of Fortuna virilis.

Peperino.—The *lapis albanus* of the ancients, now called peperino, appears to be a kind of tufa, or concretion of volcanic ashes, but somewhat more solid and durable than the other kinds. It is the material of some of the ancient Roman structures, and is found in the forum of Nerva and the temple of Antoninus and Faustina.

Tripoli.—This mineral resembles certain clays, but is rough and friable, and does not form a paste with water. It possesses a fine hard grit, and is used to polish metals and stones. Common *rotten stone* and *polishing slate* are varieties of tripoli.

Clay.—This abundant and useful earth is composed principally of alumine and silex. It possesses the valuable property of forming, when wet, a ductile and tenacious paste, which is changed by heat to a stony hardness. Common clay, of which bricks and coarse potter's ware are made, contains oxide of iron, which causes it to turn red in burning. The purer sorts, such as pipe clay, become whiter when exposed to a high heat. The earthy smell, which clays emit when breathed upon, appears also

to be owing to oxide of iron. Absolutely pure clays emit no smell. *Refractory* clays are those which endure the greatest heat without melting. The best fire-proof bricks and crucibles are made from slate clay, and contain a good deal of sand. Sometimes they are made of old materials, which have been before exposed to high heat, pounded up and mixed with fresh clay. A mixture of two parts of Stourbridge clay and one part of coke, has been found very refractory.

Asbestos.—Asbestos is a mineral of a fibrous structure. One of its varieties, called Amianthus, is composed of very delicate, flexible filaments, resembling fibres of silk. It has been manufactured into cloth and paper, which possess the property of being incombustible. It is difficult, however, to find fibres of sufficient length and firmness, to produce objects of any great use. It is sometimes mixed with clay in pottery, to increase its strength. It has also been used for the packing of steam-engines which are of high pressure, or in which steam is used at an elevated temperature.

CEMENTS.——*Limestone.*—The substances made use of for the uniting medium between bricks or stones in building, are denominated cements. The calcareous cements, composed of a mixture of lime, sand, and water, in consequence of the facility with which they pass from a soft state to a stony hardness, have in common use superseded all others. Lime, in the state of quicklime, is obtained by burning in kilns, any of those natural bodies, in which it exists in combination with carbonic acid; such as *limestone*, *marbles*, *chalk*, and *shells*. The effects of the burning, or calcination, is to drive off the carbonic acid. If quicklime, thus obtained, be wet with water, it instantly swells and cracks, becomes exceedingly hot, and at length falls into a white, soft, impalpable powder. This process is denominated the slaking of the lime. The compound formed is called a hydrate of lime, and consists of about three parts of lime to one of water. When intended for mortar, it should immediately be incorporated with sand, and used without delay, before it imbibes carbonic acid anew from the atmosphere.

Lime, thus mixed with sand, becomes harder, and more cohesive and durable, than if it were used alone. It is found that the sand used in common mortar, undergoes little or no change; while the lime, seemingly by crystallization, adheres to its particles, and unites them together.* Cements, composed in this manner, continue to increase in strength and solidity for an indefinite period, the hydrate of lime being gradually converted into a carbonate. The sand most proper to form mortar, is that which is wholly silicious, and which is sharp, that is, not having its particles rounded by attrition.

Fresh sand is to be preferred to that taken from the vicinity of the seashore, the salt of which is liable to deliquesce and weaken the strength of the mortar. The proportions of the lime and sand to each other, are varied in different places; the amount of sand, however, always exceeds that of the lime. The more sand can be incorporated with the lime, the better, provided the necessary degree of plasticity is preserved; for the cement becomes stronger, and it also sets, or consolidates, more quickly, when the lime and water are less in quantity and more subdivided. From two to four parts of sand are used to one of lime, according to the quality of the lime and the labor bestowed on it. The more pure is the lime and the more thoroughly it is beaten or worked over, the more sand it will take up, and the more firm and durable does it become.

Puzzolana.—Water cements, or hydraulic cements, often called, also, Roman cements, are those which have the property of hardening under water, and of consolidating almost immediately on being mixed. Common mortar, although it stands the effect of water very well when perfectly dry, yet occupies a considerable time in becoming so, and dissolves or crumbles away, if laid under water, before it has had time to harden. It is found that certain rocks which possess an *argillaceous* as well as silicious character, if mixed with lime or mortar, communicate to them the property of hardening in a very few minutes after the mixture has taken place, as well under

* See Brard and Vicat on this subject.

water as out of it. Substances of this sort have therefore been made the basis of water cements. The ancient Romans, who practised building in the water, and particularly in the sea, to a great extent, first availed themselves of a material of this kind. The Bay of Báiæ, from the coolness and salubrity of its situation, was a place of fashionable resort for the wealthy of Rome, during the summer months. They erected their villas, not only on the seashore, but on artificial quays and islands constructed in the water. To enable them to erect these marine structures, they fortunately discovered, at the town of Puteoli, a peculiar earth, to which they gave the name of *pulvis puteolanus*, and which is the same now known by the name of Puzzolana. This earth is a light, porous, friable mineral, various in color, and evidently of volcanic origin. When reduced to uniform powder, by beating and sifting, and thoroughly mixed with lime, either with or without sand, it forms a mass of great tenacity, which in a short time concretes to a stony hardness, not only in the air, but likewise when wholly immersed in water.

Tarras.—A substance denominated tarras, terras, or trass, found near Andernach in the vicinity of the Rhine, has been discovered to possess the same property with puzzolana, of forming a durable water cement, when combined with lime. It is said to be a kind of decomposed basalt, but resembles puzzolana. It is the material which has been principally employed by the Dutch, whose aquatic structures probably exceed those of any other nation in Europe. Tarras mortar, though very durable in water, is inferior to the more common kinds, when exposed to the open air.

Other Cements.—It has been found that various other substances, such as baked clay reduced to powder, or the common greenstone calcined and pulverized, afford the basis of very tolerable water cements, with lime. Some of the ores of manganese are also useful for the same purpose.

There are some limestones which have the property of forming water cements when calcined and mixed with

simple sand and water. This is usually in consequence of these stones containing a certain portion of argillaceous earth, united with the lime. A water cement found in New York, was used in constructing the locks of the great canal in that State. Another hydraulic cement, containing lime, silex, and alumine, has been found and applied to use in the Union Canal of Pennsylvania. Other parts of the United States have been found to afford very good hydraulic cements.*

The cause by which these compounds become hard under water, is not satisfactorily known. It has been supposed, however, and not without reason, that the great attraction for moisture existing in certain argillaceous earths, causes them to absorb immediately the superabundant moisture from the lime, and thus to expedite its solidification. This explanation is rendered more probable, by the fact, that burnt clays, which form good hydraulic cements, cease to do so, if the burning is carried so far as to vitrify them.†

* M. Berthier states that with one part of common clay and two parts and a half of chalk, a very good hydraulic lime may be made. He concludes from many experiments, that a limestone containing six *per cent.* of clay, affords a mortar perceptibly hydraulic. Lime containing from fifteen to twenty *per cent.*, is very hydraulic, and with from twenty-five to thirty *per cent.*, it sets almost instantly.

According to M. Bruyere, an excellent artificial puzzolana may be formed by heating together three parts of clay, and one part of slaked lime, for some hours, to redness.

† M. Vicat, who has experimented extensively upon the subject, has arrived at the conclusion, that the solidification of hydraulic cements formed of ordinary mortar and calcined clays, is the result of a true chemical combination, in which the lime is neutralized by the silica and alumina. But in those formed of hydraulic lime and pure sand, the solidification does not appear to result from chemical combination.

Clays which by slight calcination become good hydraulic cements, have also the same property, though in a less degree, in their natural state. It has been asserted, by M. Treussart, that the free access of air during the calcination of argillaceous cements, is of great consequence to the tenacity of the mortar and the quickness with which it hardens. To determine whether a stone will furnish hydraulic lime, M. Vicat recommends to calcine it by heat, then to slake it in the common way, and make a paste of it, which is to be placed at the bottom of a vessel of pure water. If at the end of eight or ten days it has become hard, and resists the finger, it will furnish hydraulic lime; but if it remains soft, it has the character of common lime.

Maltha.—The name of *maltha*, or *mastich*, is given to those cements into which animal and vegetable substances enter, such as oil, milk, mucilage, &c. Some of these mixtures have afforded, both to the ancients and moderns, cements of great hardness and permanency, but they are not much used.

METALS.——*Iron.*—Of all the metals, iron is the most useful, and one of the most abundantly diffused. Besides its common occurrence in earths and rocks, it is held in solution by mineral waters, it enters largely into the composition of meteoric stones, and it circulates in the blood of animals, and the sap of vegetables. The amount of iron manufactured in Great Britain in 1836, was estimated at a million of tons. Pure iron is of a bluish white color, of great hardness, malleable, ductile, and tenacious. For its fusion, it requires an intensely high temperature, equal to one hundred and fifty-eight degrees of Wedgewood's pyrometer. When combined with carbon, it forms *steel*, and is increased in hardness. At a red heat, it becomes soft and more malleable; and at a white heat, may be joined by *welding*. It is strongly attracted by the magnet, acquires itself the magnetic power, and when in the form of steel, retains it permanently. Cast iron is brittle, and fusible without difficulty, owing to the carbon which it contains. Wrought iron is flexible, and has the properties of the pure metal. In the arts, iron is applied to innumerable uses where strength and hardness are required. It is, however, deficient in durability, being readily corroded with rust, when exposed to the weather, unless protected with a coating of paint. Metallic iron is wrought, while hot, by hammering, rolling, stamping, chiselling, punching, &c.; and when cold, by the same means, also by filing, turning, drilling, cutting, and drawing. Cast iron is commonly melted, when its form is to be changed; but it is finished with common tools when cold, and may be cut with a saw when red hot. Cast iron is now the most common material used in the fabrication of machines, and in Europe it is applied to the construction of bridges, and of roofs. Ships and steam-boats of large size are now made of iron.

To the chemical compounds of iron, we are indebted for copperas, writing ink, prussian blue, &c.

Copper.—Copper is a metal of a light red color, ductile, and malleable, emitting a disagreeable odor when rubbed. It melts at twenty-seven degrees of Wedgewood. When exposed to the atmosphere, it loses its lustre, and becomes covered with a green coating, which is carbonate of copper. This coating preserves the remainder from decay, and is the source of some of its most important uses. Copper is employed to cover the bottoms of ships, and tops of houses; to form various culinary and manufacturers' vessels, also for pumps and water pipes, for engravers' plates, and for coining. When combined with acids, or oxygen, it becomes more or less poisonous, on which account, culinary vessels are coated on the inside with tin. It is this poisonous property, in part, which prevents marine animals from attaching themselves to the bottoms of coppered ships. Copper forms many valuable alloys, among which are *brass*, which consists of copper and zinc, and *bronze*, which is made of copper and tin. Its chemical compounds furnish verdigris, blue vitriol, &c. It is wrought by the same modes as iron, but is more easily malleable than that metal when cold.

Lead.—Lead has a light bluish color, with a bright lustre, which becomes quickly tarnished on exposure to the air. It is soft, heavy, very malleable, and melts at six hundred degrees of Fahrenheit's thermometer. By exposure to the heat of a furnace, it is converted into a red oxide. Lead is used for the covering of roofs, for aqueducts, for lining cisterns and tight cavities, for weights, bullets, and shot. Some of its alloys are very valuable, such as pewter, type metal, &c. Its oxides and salts afford paints of different colors, and of great use. Lead is deleterious in its influence on health, and requires great caution in those who work it, or use it, in any other than the metallic state. Injury is most frequently received, by inhaling the dust which rises in the manufactories of red and white lead. In leaden aqueducts a carbonate of lead occasionally forms; but this is insoluble in water, and subsides by its weight.

Tin.—Tin is a white metal, somewhat harder than lead, and producing a peculiar crackling sound when it is bent. It is very malleable, and is beaten for tinfoil into leaves $\frac{1}{1000}$ part of an inch in thickness. Its ductility and tenacity are not great. Tin is very fusible, melting at about four hundred and forty-two degrees of Fahrenheit's thermometer. Exposed to the atmosphere, its surface becomes slightly tarnished, but undergoes no further change. On this account, it is largely employed for coating other metals, which are more liable to oxidation. Copper vessels are lined with it, as already stated. *Tin plates* are sheets of iron coated with tin. Tinfoil with mercury forms the silvering of looking-glasses. Block tin is used to form vessels not intended for exposure to heat. Some of the salts of tin are very valuable in dyeing. The *putty* used for polishing glass, stones, and metals, is an oxide of lead and tin.

Mercury.—Mercury, or quicksilver, is fluid at common temperatures, and on this account is used in many philosophical and chemical instruments. Attempts have been made to introduce it in certain forms of the steam-engine; but it is objectionable for this purpose, from its tendency to combine with oxygen, and from the unhealthiness of its use to persons occupied about it. Mercury is employed in silvering mirrors, and large quantities are consumed in extracting silver and gold from their ores. Its alloys with other metals are called *amalgams*. It amalgamates readily with gold, silver, tin, lead, and zinc; difficultly with copper and antimony, and scarcely at all with iron and platina.

Gold.—The value derived from its scarcity, prevents the extensive use of gold in the arts. The power with which it resists tarnishing, and all changes from exposure to air and moisture, renders it desirable for many purposes, and has given rise to the art of gilding. The gold leaf used in gilding is often not more than $\frac{1}{282000}$ part of an inch thick, owing to the extreme malleability of the metal. Gold is used in coining, in jewelry, and in coloring porcelain.

Silver.—Silver possesses the same valuable properties

as gold, but is more liable to tarnish, especially when exposed to sulphurous vapors, which convert its surface into a sulphuret. Silver is very ductile, but less so than gold, and the leaves into which it is hammered, are usually three times thicker than those of gold. Its uses are well known.

Platinum.—Platinum is the heaviest substance at present known, its weight being twenty-one times and a half that of water. Like gold, it resists tarnishing from oxidation by the air, and it is furthermore capable of resisting an extremely high temperature without melting. It is very malleable, approaches to iron in hardness, and, like that metal, may be welded when hot. It is used for small crucibles and philosophical instruments; also for retorts employed in the manufacture of sulphuric acid.

Palladium.—This is a rare metal, found in minute quantities in the ores of platina and gold. Its color is between those of steel and silver. Its specific gravity is about 12. It is extremely hard, is malleable and ductile, and does not tarnish in the air. It melts at about one hundred and fifty degrees of Wedgewood. It receives a high polish, and has been used in the small way for reflectors, and for instruments requiring hardness and permanency.

Zinc.—Zinc or *spelter* is a bluish white metal, imperperfectly malleable and ductile, but rendered more so by a heat somewhat above that of boiling water. It melts below a red heat, at seven hundred degrees of Fahrenheit. When ignited, it burns with a white flame, throwing off an oxide called *flowers of zinc*. Zinc is used as a constituent in brass, and in some other alloys. It is an important material in galvanic combinations. It is easily oxidated, and therefore unfit for purposes which require durability.

Nickel.—This metal possesses a white color, and lustre resembling that of silver. It is hard, but malleable, both hot and cold, and can be drawn into wire $\frac{1}{50}$ of an inch in diameter. It is difficult to melt, and is not oxidized by air. It becomes magnetic in a degree somewhat inferior to iron, and mariner's compasses have been made of it. It is an ingredient in the compound called *German silver*.

Antimony.—Antimony is a brittle, whitish metal, of a plated or scaly texture. It is tarnished, but not otherwise altered, by exposure to the air. In type founderies, it is much used to give hardness to lead, in the alloy called *type metal.*

Cobalt.—Cobalt is a brittle metal, of a reddish gray color, and weak metallic lustre. It is somewhat magnetic, and not easily melted nor oxidized in the air. It is used in coloring glass, &c.

Bismuth.—Bismuth is a metal of a reddish white color, and brittle consistence, not readily oxidated by the air. It is very fusible, requiring little more heat than tin to melt it. It enters into various alloys, one of which is the *fusible metal*, composed of eight parts of bismuth, five of tin, and three of lead, which melts at a heat less than that of boiling water.

Arsenic.—Arsenic, in its metallic state, is of a bluish white color, easily tarnishing, brittle, and volatile at a low heat. In the state of acid, called *white arsenic*, it is well known as a violent poison. Arsenic is used in the manufactures of glass and of shot, and furnishes the basis of several brilliant pigments.

Manganese.—Manganese is a metal of a dull whitish color, brittle, extremely difficult to melt, and speedily turning to a dark oxide in the air. The native black oxide of this metal is of great use to chemists in furnishing oxygen. In the arts, it is employed in bleaching, pottery, and glass-making.

COMBUSTIBLE SUBSTANCES, &c. —— *Bitumen.* — This is an inflammable mineral substance, resembling tar or pitch in its properties and uses. Among different bituminous substances, the names *naphtha* and *petroleum* have been given to those which are fluid; *maltha*, to that which has the consistence of pitch, and *asphaltum*, to that which is solid.

Amber.—Amber is a yellowish, translucent, inflammable mineral, hard enough to receive a fine polish, capable of being wrought into various ornamental articles, and forming an ingredient in some varnishes and lackers.

Coal.—This well-known combustible is composed es-

sentially of carbon, with a proportion, greater or less, of bitumen, a little sulphur, and a remainder of earthy and incombustible matter. True coal burns with a white flame, a black smoke, and bituminous odor. Some kinds, as the Cannel coal, burn readily, with a large flame, and without softening or concreting. Others, as the Newcastle, Liverpool, and Orrel, concrete, or cake, during combustion, and last longer. The poorer coals have usually a large admixture of foreign and incombustible substances. Coal is of great value as a fuel, both in the arts, and for domestic purposes. As it contains more combustible matter, in a given volume, than wood, it is capable of evolving and sustaining more heat than that fuel, within the same furnace, or other cavity. When coal is exposed to heat, but prevented from burning, by the exclusion of the air, it loses its moisture and bituminous portion, and is converted into coke, a fuel bearing the same relation to coal, as charcoal to wood. Coal has of late years been usefully applied to the production of inflammable *gas*, for the purposes of illumination.

Anthracite.—This combustible, of which the Lehigh, Schuylkill, and Rhode Island coal, are specimens, is harder, heavier, and less black, than the true, or bituminous coals. It burns slowly, without smoke, and with a faint flame. It is more difficult to kindle than most fuels, owing to its greater conducting power, and the high temperature necessary for its combustion; but when once on fire, it produces an intense and lasting heat. It is more durable than the bituminous coals, but requires to be burnt in masses large enough to sustain a high temperature. Anthracite has now become a common fuel in many parts of the United States, and is highly valuable, both for domestic and manufacturing purposes. It is burnt in various furnaces, forges, stoves, and grates constructed for the purpose. In iron works, it is found to occasion less oxidation and scaling of the metal, than any other fuel. But in reverberating furnaces, where a blaze is required, it does not answer the requisite purpose. Most of the anthracites afford inflammable gas, not, however, suitable for purposes of illumination.

Graphite.—This mineral, otherwise called *plumbago* and *black lead*, is composed of carbon, with a portion of iron. It is unctuous to the touch, and soils the fingers. It is used for pencils and crayons, and, mixed with clay, is formed into crucibles. Black-lead pencils are made, by inserting the straight edge of a plate of graphite, into a groove made in the wood, and sawing it off, leaving a slender rod of the lead enclosed, which is afterwards covered with wood.

Peat.—Peat is a substance of vegetable origin, dug from bogs and marshes, and capable of reproducing itself in places from which it has been removed. Peat, when dry, is combustible, and is used as such, where better fuel cannot be obtained.

Sulphur.—Sulphur is a simple inflammable body, melting at two hundred and twenty degrees, and taking fire at five hundred, of Fahrenheit. When kept melted for some time, at about three hundred degrees, Fahrenheit, it becomes thick and viscid, and if poured into a basin of water, it becomes ductile, like wax. In this state, it is used for taking impressions of seals. It is also used to form moulds for plaster casts. Sulphur is an ingredient in gunpowder, and enters into many chemical compounds, which are of great use in the arts. Sulphur is burnt to produce sulphuric acid.

MATERIALS FROM THE VEGETABLE KINGDOM.

Wood.—The woody portion of the trunks of trees, is made up of minute tubes or vessels, running longitudinally, having their sides strengthened with rigid fibres, and their interstices filled with cellular substance. In the common trees of temperate climates, these vessels are arranged in concentric layers or cylinders ; one layer being added for each year of the tree's growth. The outer layers, being those which transmit the sap, are more porous, soft, and perishable, and are known by the name of *alburnum* or *sap wood.* The inner layers are commonly darker colored, more solid, compact, and durable ; and are known by the name of *heart wood.* The heart wood is preferred for most purposes in the arts, its vessels having become in

part obliterated by age, and its density and strength increased. Boards are least liable to warp when they are cut through the centre or pith of the trunk. All wood shrinks in drying, and decays when exposed to the weather; but different trees vary greatly from each other in this respect.

Bark.—Bark is the external investment of the trunks and branches of trees, and consists, when young, of three coats or layers, called the *cuticle*, the *cellular integument*, and the *liber* or inner bark. But during every season, a new liber grows on the inside of the former ones, and pushes them outward, so that old bark is found to consist of numerous *cortical layers*, each of which was originally a liber. The outermost of these layers gradually become dead and dry, and merely augment the thickness of the bark, without adding to its usefulness in the arts.

Oak.—Numerous species of the oak tree are found in the United States. They are generally distinguished for great strength, but are coarse grained, and prone to warp and crack under changes from moisture to dryness. The live oak of the Southern States (*Quercus virens*) is prized in ship-building, beyond any native timber. The white oak (*Quercus alba*) is employed for the keels, side timbers, and planks of vessels, also for frames of houses, mills, and machinery requiring strength; for wagons, parts of carriages, ploughs, and other agricultural instruments. Large quantities are consumed for the staves and hoops of casks, for which they furnish one of the best materials. The bark of the black oak (*Quercus tinctoria*) furnishes the *quercitron* used by dyers. Most of the species of oak are employed in tanning, and they all furnish a valuable fuel.

Hickory or *Walnut.*—The wood of the different species of native walnut or hickory (*Juglans*, or *Carya*) is eminently distinguished for weight, tenacity, and strength. It has, however, important defects. It warps and shrinks greatly, decays rapidly when exposed to the weather, and is very liable to the attacks of worms. On these accounts, it is never used for house or ship building, but is chiefly employed for minor purposes, where strength is

the chief requisite; as in the teeth of mill wheels, screws of presses, handspikes, capstan bars, bows, hoops, and handles of tools. As fuel, the hickory stands at the head of native trees, and commands a higher price than any other wood.

Ash.—The white ash (***Fraxinus Americana***) and some other species, are of great utility in the arts. Ash wood is strong, elastic, tough, and light, and splits with a straight grain. It is also durable, and permanent in its dimensions. It furnishes the common timber used in light carriages, for the shafts, frames, springs, and part of the wheels. Flat hoops, boxes, and the handles of many instruments are made of it. It is almost the only material of oars, blocks of pulleys, cleats, and similar naval implements, in places where it can be obtained.

Elm.—The common American elm (***Ulmus Americana***) is valued for the toughness of its wood, which does not readily split. On this account, it is chiefly used for the naves, among us commonly called *hubs*, of carriage wheels.

Locust.—The common locust (***Robinia pseudacacia***) is one of the hardest, strongest, and most valuable of native trees. The larger pieces of its timber are used in ship-building, and the smaller pieces are in great request to form the treenails* or pins which confine the planks to the timbers. This tree is liable, in the Northern States, to be perforated by an insect, so that it is often difficult to procure sound pieces of any considerable size. Locust wood is exceedingly durable, when exposed to the weather; and forms excellent fuel.

Wild Cherry-tree.—The wood of this tree (***Prunus Virginiana***) is of a deep color, hard, durable, and, when properly seasoned, very permanent in its shape and dimensions. In the manufacture of cabinet work, it is much used as a cheaper substitute for mahogany. On the Western rivers, it is sometimes used in ship-building.

Chestnut.—The American chestnut (***Castanea vesca, B.***) is a large tree of a rapid growth. Its wood is coarse

* Commonly pronounced *trunnels.*

and porous, very liable to warp, and seldom introduced into building or furniture. It is chiefly used for fencing stuff, to which use it is fitted by its durability in the atmosphere. Chestnut is an unsafe fuel, in consequence of its tendency to snap, and throw its coals to a distance.

Beech.—The wood of the red beech (*Fagus ferruginea*) is liable to decay when exposed to alternate moisture and dryness. It does not, however, readily warp, and being smooth grained, it is used for some minor purposes, such as the making of planes, lasts, and card backs. It forms a very good fuel.

Basswood.—The American linden or basswood tree (*Tilia Americana*) produces a fine-grained wood, which is very white, soft, light, and flexible. It is sometimes employed for furniture, but its chief use is to form the panels of coach and chaise bodies, for which its flexibility makes it well suited.

Tulip Tree.—(*Liriodendron tulipifera.*) The boards of this tree are sold under the name of *white wood*, and erroneously under that of *poplar*. Its wood is smooth, fine grained, easily wrought, and not apt to split. It is used for carving and ornamental work, and for some kinds of furniture. In the Western States, where pine is more scarce, the joinery, or inside work, of houses, is commonly executed with this material, and sometimes the outer covering. In common with basswood, it forms an excellent material for coach and chaise panels.

Maple.—The rock maple, (*Acer saccharinum*,) and several other species, afford wood which is smooth, compact, and hard. It is much used for cabinet furniture, and is a common material for gunstocks. The wood in some of the old trunks, is full of minute irregularities, like knots. These, if cut in one direction, exhibit a spotted surface, to which the name of *bird's eye* maple is given; while if cut in another direction, they produce a wavy or shaded surface, called *curled* maple. This last effect, however, is more frequently produced by a mere serpentine direction of the fibres. The distinctness of the grain may be increased by rubbing the surface with diluted sulphuric acid. Maple wood forms a good fuel.

It is not very lasting, when exposed to the weather. The sap of the rock maple, and of one or two other species, yields sugar on being boiled.

Birch.—The white or paper birch (*Betula papyracea*) has properties similar to those of the maple, and is appropriated to the same uses. Its cuticle or outer bark, is made by the Indians into canoes. The lesser white birch (*B. populifolia*) is a perishable tree, of little value. The black birch, (*B. lenta*,) known for its aromatic bark, affords a firm, compact, dark-colored wood, much valued for furniture, and sometimes used for screws and implements requiring strength. The yellow birch (*B. lutea*) is applied to the same uses as the last, and makes good fuel.

Buttonwood.—The buttonwood or plane tree (*Platanus occidentalis*) is in some of the Northern States improperly called *sycamore*. It is one of the largest inhabitants of the forest, and Michaux states that trees are found in the Western States which measure forty feet in circumference. This majestic tree is chiefly valuable for its shade, as the wood is perishable, and prone to warp.

Persimmon.—(*Diospyros Virginiana.*) The heart wood is dark colored, compact, hard, and elastic ; and is used in the Southern States for screws, shafts of chaises, and various implements.

Black Walnut.—(*Juglans nigra.*) This tree is rarely found north of New York. Its heart wood is of a violet color, which, after exposure to the air, assumes a darker shade, and finally becomes nearly black. This wood, when deprived of its white part, or sap, remains sound for a long time, even if exposed to air and moisture, and is not attacked by worms. It is very strong and tenacious, and when seasoned is not liable to warp or split. It is used in the Middle and Western States for furniture, for gunstocks, for naves of wheels, and, to a certain extent, in house and ship building.

Tupelo.—Different species of the genus *Nyssa* have received, in the United States, a great variety of common names, among which *tupelo*, *pepperidge*, and *gum*

tree are the most common. In Massachusetts, the name *hornbeam* is improperly applied to one of them. Their wood is smooth grained, and remarkable for the decussation or interweaving of the fibres, which renders it almost impossible to split the logs. This quality causes several of the species to be in demand for naves of wheels, hatter's blocks, and implements requiring lateral tenacity.

Pine.—The American pines exceed all other native trees for the value and variety of their uses. The white pine (*Pinus strobus*) has a very tall, straight trunk, the wood of which is light, soft, homogeneous, and easy to work. It is remarkably exempt from the common fault of timber, that of decaying in the open air, and of changing its dimensions with changes of weather. On these accounts, it is extensively employed for most of the common purposes of timber. In the Northern States, masts of vessels are commonly made of it. Frames of houses and of bridges are also formed of it ; its defect of strength being more than balanced by its steadiness and durability. Its boards form almost the only material used in the Northern States for the joiner's work, or inside finishing of houses ; and for this use it is exported to other countries. Ornamental carving is commonly executed in this material. The southern pitch pine (*Pinus palustris, L.*) covers extensive *barrens* in the Southern States, and yields vast quantities of tar and turpentine. Its wood is appropriated to the same objects as that of the white pine, but is harder and stronger, and therefore preferred for planks, spars, floors, decks, &c. Many other species of pine exist on this continent, partaking qualities like those already described, but most of them harder than the white pine.

Spruce.—The black and white spruce belong to the race of trees commonly called *Firs*. They are both valuable, but the black spruce (*Pinus nigra*) unites in a peculiar degree the qualities of strength, elasticity, and lightness, together with the power of resisting exposure to the weather. It is much sought after for the smaller spars of vessels, such as the booms, yards, and topmasts.

Hemlock.—The hemlock tree (*Pinus Canadensis*) is

inferior to the other firs in quality, though it grows to a large size. It is coarse grained, often twisted, and cracks and shivers with age. It furnishes an inferior sort of boards, used in covering houses. Its bark is valuable in tanning.

White Cedar.—This tree (*Cupressus thuyoides*) occupies large tracts denominated cedar swamps. The wood is soft, smooth, of an aromatic smell, and internally of a red color. It is permanent in shape, and very durable; and esteemed as a material for fences. Large quantities of shingles are made of it. It is a favorite material for wooden wares, or the nicer kinds of cooper's work.

Cypress.—The cypress tree of the Southern States (*Cupressus disticha*) is light, soft, and fine grained; and at the same time elastic, with a considerable share of strength. It sustains heat and moisture for a long time, without injury. In the Southern States, and on the Mississippi, it is much employed for fences, and for the frames, shingles, and inside work of houses.

Larch.—The American Larch (*Pinus microcarpa*) is called *hackmatack* and *tamarack*, in different parts of the Union. Its wood is strong, elastic, and durable; and is highly prized, in places where a sufficient quantity can be obtained, for naval and civil architecture.

Arbor Vitæ.—This tree (*Thuya occidentalis*) is of the middle size, and frequently called white cedar. The wood is reddish, fine grained, very soft, and light. It bears exposure to the weather, with very little change, and is esteemed for the posts and rails of fences.

Red Cedar.—(*Juniperus Virginiana.*) The name of *savin* is in some places improperly applied to this tree. Unlike the white cedar, it grows in the driest and most barren soils. The trunk is straight, and knotted by small branches. The heart wood is of a bright red color, smooth, and moderately soft. It exceeds most other native trees in durability, and is in particular request for posts of buildings, though it is difficult to obtain it of large size.

Willow.—The most common kinds of *Salix* or willow,

about our sea-ports, are European species which have become naturalized. Their wood is soft, light, and spongy. Willow charcoal is used in the manufacture of gunpowder. The osier and some other species, with long slender shoots, are extensively cultivated to form wicker work, such as baskets, hampers, and the external coverings of heavy glass vessels.

Mahogany.—In the manufacture of cabinet furniture, mahogany (*Swietenia mahagoni*) has taken precedence of all other kinds of wood. Its value depends not so much on its color, as on its hardness, and the invaluable property of remaining constant in its dimensions, without warping or cracking, for an indefinite length of time. The same qualities which render it suitable for furniture, have given rise to its employment for the frames of philosophical instruments, and of delicate machinery. Mahogany is imported from the West Indies, and different parts of Spanish America.

Teak Wood.—(*Tectona grandis.*) The teak tree is a lofty inhabitant of the forests of India, and affords a kind of timber of the highest value in ship-building. This wood is exceedingly hard, firm, and durable, and many vessels are built of it in the British Eastern dominions.

Lance Wood.—(*Guatteria virgata.*) This is a tree of middle size, growing in the West Indies, whence it is imported chiefly to form the shafts of carriages. It is peculiarly tough, strong and elastic, and surpasses any of our native woods in this respect. Its grain is more close than that of ash, and is therefore more suitable for carving and for receiving varnish.

Boxwood.—The box tree (*Buxus sempervirens*) is imported from the south of Europe. Its wood is of a well-known yellowish color, hard, compact, smooth, tough, and not liable to crack. Musical wind-instruments are commonly made of it; also mathematical measuring instruments. The handles of many tools, and various articles of turners' work, consist also of this material. Wood engravings are cut upon the end of the grain of boxwood.

Lignum Vitæ.—The wood of the *Guiacum officinale*

is employed in the arts under this name. It is dark colored at the heart, strong, exceedingly hard, and so heavy as to sink in water. It is impregnated with resin, and on this account durable in liquids. Handles of tools, boxes of gudgeons, wheels of pulleys, castors, balls, stop-cocks, mallets, &c., are made of it. It is imported from the West Indies and South America.

Several other tropical woods are imported for use by cabinet-makers, such as *rose wood*, *ebony*, *satin wood*, &c. They are generally hard, colored woods, susceptible of a fine polish. Satin wood (*Swietenia chloroxylon*) is thought poisonous to the hands of the workmen.

Cork.—Cork is a fungous substance growing on the bark of a species of oak (*Quercus suber*) in the south of Europe. Its lightness and elasticity give it an aptitude for certain purposes, in which it would be difficult to find a substitute.

Hemp.—Hemp is the fibrous portion of the bark of an annual plant, (*Canabis sativa*,) and is of great use in the manufacture of cordage and canvass. The fibres are separated from the rest of the stalks, by the decomposition of the latter. In the process of *dew rotting*, the hemp is exposed on the grass for a number of weeks to the weather. In that of *water rotting*, it is immersed for a part of the time in water, and subsequently exposed to the weather. By these processes, the solid parts of the hemp decay; while the flexible fibres remain strong and but little impaired. The decayed portion is afterwards broken up, by the operations of an instrument called a brake; and sometimes by a mill or stone roller. The chaff is separated from the fibres by the strokes of a wooden scotching or swingling knife; and the fibres still further cleansed by combing them on an instrument called a heckle.

Flax.—Flax is also the fibrous bark of an annual plant, (*Linum usitatissimum*,) which is smaller and finer than hemp; and constitutes the material of linen cloth. Flax is rotted, and subsequently dressed, much in the same manner as hemp. When, however, it is intended for finer uses, as for cambric, lace, &c., it is scraped with a

blunt knife upon leather, and the fibres separated and straightened with a brush. A method has been introduced in England, of dressing, by machinery, flax, in its recent state, *without rotting*. This method is represented as highly economical, affording more flax, and of a stronger texture, than that produced in the common way.* The fibres of flax and hemp are long, straight, and unyielding, so that they cannot well be spun by the same machinery which is used for cotton and wool. When viewed through a microscope, they are found to be cylindrical and jointed, like a cane.

Aloes.—A large family of tropical plants are known by the name of Aloes. The leaves are thick, juicy, and thorny, and afford the drug known by the same name. The leaves of some species contain a fibre, which, when twisted into ropes, is said to be several times stronger than those of hemp prepared in the same way. They contain a resinous substance which renders tarring unnecessary.

Pine-apple.—The pine-apple plant is well known, and valued for its delicious fruit. It has lately been found that its leaves contain an extremely fine, glossy, and silken fibre, easily separable by beating and washing. The ultimate fibres are finer than those of cotton or linen, and are applicable to the same purposes.

Several species of *Agave* also afford from their leaves very strong, flexible fibres, one of which is known by the name of *Sisal hemp*.

Manilla Hemp.—The white hemp brought from the East Indies, is said to be obtained from a species of *Musa* or plantain tree. Its fibres are long, whitish, parallel, and exceedingly strong. They are now extensively manufactured into cordage in this country. Ropes made of it are light, elastic, and strong, but do not admit of being tarred in the manner of common ropes.

New Zealand Flax.—(*Phormium tenax.*) This plant was employed by the natives of New Zealand for cordage and clothing, at the time of the discovery of that

* See Brande's Quarterly Journal, vol. iv. p. 329.

island. It produces one of the strongest vegetable fibres known, having a fine, white, silken appearance. It is readily cultivated in Great Britain and Ireland, and has lately become a subject of attention among manufacturers. This plant, like the Manilla hemp, receives tar with difficulty, when made into cordage; but this defect is said to be overcome by steeping it forty-eight hours in a weak solution of potash or soda.

Cotton.—Cotton is the product of the *Gossypium herbaceum*, an Oriental plant, now cultivated in most parts of the world, which possess a sufficiently warm climate. It grows in pods, forming a light, woolly investment to the seeds; and seems intended by Nature to assist in their dispersion by the winds. The fibres of cotton are extremely fine, delicate, and flexible. When examined by the microscope, they are found flat like a ribbon, with a border like a hem on each side. Their direction is not straight, but contorted; so that the locks can be extended or drawn out without doing violence to the fibres. These properties render cotton peculiarly adapted for the operations of machinery, and have given employment to a vast amount of manufacturing skill and industry, both in Great Britain and this Country.

Cotton, after being gathered, is cleansed from the seeds by a machine called a *gin*, of which there are two kinds. The *roller gin* consists essentially of two small cylinders revolving in contact, or nearly so, with each other. The cotton is drawn between these rollers, while the seeds, being too large to pass, are left behind, and fall out on one side. The *saw gin*, invented by Mr. Whitney, is intended for those sorts of cotton, the seeds of which adhere too strongly to be separated by the former method. It consists of a receiver, having one side covered with strong parallel wires, placed like those of a cage, and about an eighth of an inch apart. Between these wires enter an equal number of circular saws, revolving on a common axis. The teeth of these saws entangle the cotton and draw it out through the grating of wires, while the seeds are prevented by their size from passing. The cotton thus extricated is swept off from the teeth of the

saws by a revolving cylindrical brush; and the seeds fall out at the bottom of the receiver.

Straw.—The wheat straw, used in Tuscany, in the manufacture of Leghorn hats, is gathered before the ear is ripe, the wheat having been sown very close, so that it is produced of an inferior or dwindled size. It is bleached by exposure to the dew, sun, and air, and afterwards by fumigation with sulphur. It may also be bleached by chloride of lime. The straw, thus produced, is woven into braids, which are afterwards joined at their edges, to form hats. In this country, hats of great delicacy have been made from various species of grass.

Palm Leaves.—The leaves of the large fan-leaved palm are plaited, fibrous, and firm. In tropical climates, they are much used for fans. Of late years, these leaves have been imported into the Northern States, in great quantities, as a material for the manufacture of hats. They are split by machinery into narrow, even strips, which are afterwards braided in the manner of straw.

Turpentine.—Turpentine is the juice which exudes from pine trees. The Southern pitch pine furnishes most of that used in commerce. It is procured by making incisions, or cavities, in the trunk, and dipping out the turpentine which collects. *Tar* is an impure turpentine, obtained by burning. The resinous parts of the wood, called *lightwood*, are collected in pits, and being set on fire at the top, a part of the turpentine is burnt, while the rest is melted and flows out at the bottom. *Pitch* is tar inspissated by boiling or burning. If turpentine be distilled, the volatile portion, which passes over, is the *oil* or *spirit* of turpentine, while the solid part left behind is *rosin*.

Caoutchouc.—This substance, called also *elastic gum*, and *India rubber*, is obtained from different vegetables, but chiefly from the *Jatropha elastica*. It exists in the form of juice, and is dried by applying it, in successive coatings, to clay moulds of various shapes. After it is dry, the clay is crushed and shaken out. This substance is wonderfully flexible and elastic, and restores itself instantly, after being extended to many times its original

dimensions. It is inflammable, and used by the inhabitants of Cayenne for lights. It is insoluble in water, and in alcohol ; but dissolves in ether, and in oils. These solutions have been used for varnishes, but have the disadvantage that they do not readily dry. Water of ammonia dissolves caoutchouc slowly, requiring to be digested with it for some months. A mixture of oil of turpentine and alcohol,* is a solvent which has the property of drying more readily and restoring the elastic properties of the gum. The purified naphtha from coal tar has the same property.† If caoutchouc be distilled at six hundred degrees of Fahrenheit, a liquid is obtained which dissolves caoutchouc, and also copal and other resins. It is the lightest of known liquids, and its vapor is heavier than any gas.‡ Slips of India rubber may be made to cohere by boiling them in contact for a certain time in water, and in this way some articles are made. When heated to about two hundred degrees of Fahrenheit, this substance may be spread by rollers upon cloth, so as to form a permanent coating. Caoutchouc is of great use in the formation of many instruments, which require to be elastic, and impenetrable to water. Shoes are now made of it in great numbers, and are found to exclude perfectly the wet. The solution of this gum, spread upon leather and cloth, renders them water-proof, and even air-tight. The manufacture of India rubber cloths has given rise to

* Chaptal. Chimié appl. aux. Arts.

† Turner's Chemistry.

‡ Mr. Faraday states that the liquid caoutchouc, or juice, as it came from the south of Mexico, was a pale, yellow, thick, creamy-looking substance, of a uniform consistency, with a disagreeable acescent odor. When exposed to the air in films, it is soon dried, leaving caoutchouc of the usual appearance and color. One hundred parts of the sap left nearly forty-five of solid matter. Heat caused an immediate coagulation of the sap, the caoutchouc separating in a solid form. When the sap is purified by repeated washings with water, the caoutchouc rises each time to the surface ; it is obtained of a white color, and afterwards, when perfectly dry, it becomes transparent, colorless, and elastic. A solution of caoutchouc in oil was obtained by mixing the juice with olive oil, and heating the mixture so as to drive off the aqueous parts. This promises to be a useful element in varnishes. See Brande's Journal, No. xli. page 19.

a new branch of industry within a few years past. An elegant elastic web is made from fibres of caoutchouc wound with silk and woven. The elasticity which is lost by stretching, is restored by a hot smoothing-iron. Its adhesiveness and friction are the properties by which India rubber erases black lead from paper.

Oils.—Oil is an inflammable liquid, which does not unite with water. *Volatile oils* are those which evaporate, or may be distilled without change, by a moderate heat. Of these, the oil of turpentine is an example. They are used in the arts for solvents, and in varnishes. *Fixed oils* are those which do not evaporate without decomposition, or chemical change. They produce an unctuous stain, which is not discharged by heat. They do not boil at a temperature much short of that of melting lead. They unite with alkalies, forming soaps. Some of them are called *fat oils*, which do not lose the unctuous character on exposure to the atmosphere, but assume a state like that of tallow; such, for example, as olive oil. Others are called *drying oils*, which become solid in the air, after exposure for a certain time, and remain transparent. This is the case with linseed oil. Fat oils are used in the arts, to give flexibility to other materials; to diminish their friction, and to protect them from water. Drying oils are largely consumed as ingredients in paints, printers' ink, and varnishes.

Resins.—Various resinous substances are employed in the arts. They are fusible, inflammable, soluble in oil and alcohol; but insoluble in water. For ordinary purposes the *rosin* of the pine is employed, being the cheapest. For varnishes, *copal*, *mastic*, *animé*, and some others are used. The basis of sealing wax is the resin called *lac*, which is deposited on trees in India by an insect.

Starch.—Starch or *Fecula*, is a white substance, obtained from farinaceous grains and roots. It is insoluble in cold water, but dissolves readily in hot water. In alcohol it does not dissolve. In Europe, starch is commonly made from wheat. In this country it is prepared, for manufacturing purposes, from potatoes. For this ob-

ject, the potatoes are rasped, or ground up, by a machine, to a pulp. This pulp, when washed with cold water, yields a white powder, which, on subsiding, proves to be pure starch. It is heavier, and goes further, for practical purposes, than the starch of wheat. Starch is largely consumed in cotton factories in the process of dressing, &c.

Gum.—The true gums are those which dissolve in water, either hot or cold, and form with it a thick, mucilaginous solution. They do not dissolve in alcohol, nor melt by heat. The species principally used, are, the *gum arabic*, *gum tragacanth*, and *gum senegal*. Gum, in the state of mucilage, is employed to give firmness and lustre to linen. Calico printers use it in great quantities, to give their colors such a degree of consistency, as will prevent them from running upon the cloth. It is made to form an ingredient in writing ink, and in water colors, for the same reason.

MATERIALS FROM THE ANIMAL KINGDOM.

Skins.—The *cutis*, or true skin of animals, from which leather is made, is composed of fibres irregularly situated, and closely interwoven. They are capable of being dissolved by long boiling in water, and are found to consist almost wholly of gelatin, or glue. The skins of a great variety of animals are used in the manufacture of leather. It has been found that those skins which are most flexible, and most easily dissolved, afford the poorest leather and the weakest glue; while those which are tough, and difficult of solution, yield leather and glue of the best quality.

Hair and Fur.—The hairs of animals consist of slender, flexible tubes, having a consistence like that of horn, and possessing the chemical properties of coagulated albumen. The surface of hairs is covered with minute scales or asperities, which give them a rough feel when they are rubbed upwards; and which cause them to entangle each other in the processes of *felting* and *fulling*. *Fur* consists of very fine hair, thickly set, and commonly contorted. It is a very slow conductor of heat, and is provided by Nature for the clothing of animals in high latitudes. Hair is a durable and very elastic substance, and

is converted to many useful purposes. By means of a linen warp, it is woven into cloth for furniture. It forms the most elastic stuffing for cushions and mattrasses. It is combined with mortar in plastering, to increase its cohesiveness. Furs are converted to important uses, in clothing and in felting.

Quills and Feathers.—The structure of the quills and feathers of birds is remarkably fitted to combine strength and elasticity with lightness; the mechanism of the tube, shaft, and feathering, being all adapted to this purpose. The tube or barrel of a quill, consists of two laminæ or layers, the outermost of which has transverse fibres, and the inner, longitudinal. It is the first of these, which is scraped off to prepare the quill for splitting. Quills are rendered transparent by exposing them to heat and moisture. The process recommended by M. Schloz, is to expose the quills to hot steam, by suspending them in a covered vessel, which contains water in the bottom, and is kept boiling for four hours, the quills being immersed in the vapor only. At the end of this time, they are withdrawn, and the next day cut, wiped, and dried with a moderate heat. *Feathers*, as they are obtained from common birds, and *down*, which is procured from the aquatic birds of northern climates, are among the most elastic substances known, and also the slowest conductors of heat. These properties are the foundation of their usefulness. The chemical composition of feathers is nearly similar to that of hair.*

Wool.—Wool is a fine, soft, long, and contorted hair, derived chiefly from the sheep. It is said to be the result of cultivation, and not to be found in the wild sheep, which is covered with short hair. Removal to a tropical climate causes the fleeces of sheep to fall off, and to be succeeded by a covering of short hair. Wool is an invaluable material in the clothing of civilized nations. The fineness and position of its fibres enable it to be drawn out like cotton, and to be spun by machinery. Their rough-

* Feathers are purified by exposing them to heat; also by immersing them in lime-water for several days, and afterwards washing them with pure water, and drying. This process extracts the animal oil.

ness and tendency to curl, cause the fibres to be consolidated in the process of felting.

Silk.—Silk is spun by the larvæ or caterpillars belonging to different species of *Phalæna*. It forms the ball, or *cocoon*, in which the silk-worm envelopes itself in passing to the chrysalis state. The fibre, which constitutes this ball, is so small, that a single thread, when unwound, is often twelve hundred yards in length. The original threads are too fine for manufacturing purposes, and therefore, in winding or reeling them off from the cocoons, the ends or threads of several cocoons are joined together, and reeled out of warm water, which softens their natural gummy covering, and causes them to cohere into a single thread. Silk, as it is spun by the animal, is of a color varying from white to reddish yellow. Its texture is very strong and elastic. It communicates to water a mucilaginous character, owing to the solution of its gummy part; but the silk itself is insoluble in water or alcohol.

Bone and Ivory.—The bones of animals are composed of a white, hard, lamellar, substance, consisting chiefly of phosphate of lime, with a small portion of other earths, and impregnated with oily and gelatinous matter. Exposure to heat causes them to soften and crumble. Bone is used in the arts for the handles of cutlery, and various articles of turners' work. It is whitened by exposure to the sun and weather, and sometimes by the use of chlorine gas. It is wrought by sawing, turning, &c., and polished with pumice and tripoli. *Ivory* is the material of the elephant's tusks. It agrees with bone in its principal properties, but is more compact, hard, and white, and receives a finer polish. When burnt in close vessels and afterwards reduced to powder, it furnishes the pigment called *ivory black.*

Shell.—The *shells* of marine animals differ from bone in being composed of carbonate, instead of phosphate of lime. They are therefore burnt, in some places on the seacoast, to afford lime for mortar. The inside of the shell of the pearl oyster affords a beautiful substance called mother of pearl, which is manufactured into toys, counters, handles of cutlery, &c.

Horn.—Horn differs from bone, not only in its texture, which is softer, but also in its composition, being composed chiefly of animal matter, resembling coagulated albumen, and containing but little lime. Horn, when heated, becomes soft, flexible, and plastic, capable of being cemented and pressed by moulds into a great variety of shapes.

Tortoise Shell.—This substance exists in the form of plates on the outside of the shell of a species of sea turtle (*Testudo imbricata.*) It resembles horn in its general properties, and like that article may be wrought by softening it in boiling water, and subjecting it, while hot, to pressure in moulds. The edges of different pieces, by pressing them with heated irons, may be joined together and made to cohere firmly.

Whalebone.—This substance is obtained from the mouth of several species of whale, where it exists in the form of plates arranged on the outer edge of the upper jaw. These plates terminate in a kind of hair. Whalebone, in its texture and chemical properties, is very similar to horn. It is strong, light, and elastic; on which accounts, it is applied to various mechanical uses. Whalebone, when heated by steam, or boiling water, becomes more flexible, and if bent into any shape, retains its form on cooling. Hence it has been manufactured into various woven fabrics. It may be cemented in the same way as horn or turtle shell.

Glue.—The skins, tendons, membranes, &c., of animals, are composed principally of a substance known in chemistry by the name of *gelatin.* This substance is not soluble in cold water, but dissolves freely in boiling water, and on cooling assumes the state of gelly. It has great affinity for *tannin*, which exists in astringent barks; and on this affinity depends the manufacture of leather. Common glue is impure gelatin, obtained from hoofs, ears, and refuse portions of hides. These are first cleansed, then boiled to a gelly, which, on cooling, is cut into squares and dried upon nets. *Size* is a finer kind of glue, made with more care, from select materials. *Isinglass* is a still more delicate sort, prepared from the swimming-bladders

of fish. Glue is a cementing material of unequalled strength, for wood and fibrous substances. It is employed, in different states of purity, by carpenters, hatters, paper makers, linen manufacturers, gilders, painters in distemper, and refiners of liquors. In the state of a stiff gelly, it forms, with treacle, the elastic rollers, used to distribute and apply the ink, in printing.

Oil.—The oil of animals belongs to the class of fixed and fat oils. The oil of those animals which live in a cold medium, as whales, remains fluid at common temperatures ; but that of most land animals becomes solid, when cooled below the heat of the living body. *Tallow*, the hardest kind, is obtained from ruminating quadrupeds. Animal oils are appropriated to the same purposes as the vegetable ; but their great use is to furnish light, by their combustion.

Wax.—Wax, in its crude state, is obtained by melting the honeycomb of the bee. It is commonly classed with vegetable substances ; but the experiments of Huber have shown, that it is produced by the bees themselves, and not gathered by them directly from plants, as was formerly supposed. Wax melts with a gentle heat, at one hundred and forty-two degrees of Fahrenheit, is inflammable, dissolves in boiling alcohol, ether, and fixed oils ; but is insoluble in water. Beeswax is deprived of its coloring matter by bleaching. To effect this, the melted wax is suffered to run through holes in the bottom of a vessel, upon the surface of a cylinder which is kept revolving in water, by which means the wax is spread out, and cooled in the form of thin laminæ or ribands. It is then exposed to the light and air upon frames, and occasionally wet, till the bleaching is completed. Bayberry, or myrtle wax, is a harder substance than beeswax, obtained from the berries of the *Myrica cerifera*, by boiling them in water.

Phosphorus.—Phosphorus is a simple combustible body, usually obtained from animal bones. It is of a soft, waxy, consistence, and is luminous in the atmosphere at common temperatures. At one hundred and forty-eight degrees of Fahrenheit, it takes fire and burns with great brilliancy. On this account, it should be kept in water.

Phosphorus is the agent, in some kinds of apparatus, for procuring fire.

WORKS OF REFERENCE.—Among the works, which may be usefully consulted on the subjects of this chapter, are CLEVELAND'S Mineralogy, 2 vols. 8vo. 1822;—BRARD, *Minéralogie appliquée aux Arts*, 3 tom. 8vo. Paris, 1821; EVELYN'S Sylva, 2 vols. 4to. edit. of 1812; MICHAUX, North American Sylva, 3 vols. 8vo. 1817;—TREDGOLD'S Elementary Principles of Carpentry, 4to. 1820;—THOMSON'S Chemistry;—URE'S Dictionary of Chemistry;—VICAT, *Recherches sur les Chaux, &c.*; URE'S Dictionary of the Arts, 1839.

CHAPTER III.

OF THE FORM AND STRENGTH OF MATERIALS.

Modes of Estimation, Stress and Strain, Resistance, Extension, Compression, Lateral Strain, Stiffness, Tubes, Strength, Place of Strain, Incipient Fracture, Shape of Timber, Torsion, Limit of Bulk, Practical Remarks.

WHEN materials are employed for mechanical purposes, the power or strength with which they resist external force, depends not merely upon the nature of the material, but upon its shape, its bearings, and upon the manner in which force is applied to it. It is, therefore, important, to consider, not only the qualities of individual substances, but likewise the laws, which are common to different materials, by which they act in resisting mechanical change, from forces applied to them.

Modes of estimation.—Two methods are employed in estimating the strength of materials, in different forms and situations; one by mathematical computation, the other by actual experiment. Neither method is to be looked upon as precisely accurate in its results; yet these results furnish approximations to truth, which, in many cases, it is very useful to understand.

Stress and strain.—Professor Robison, and some other writers on the strength of materials, have enumerated four modes, commonly called strains, by which any force or

stress acting upon a solid body may operate to overcome the cohesion of its particles. These are, 1. By *extension*, producing a tendency to rupture ; as in the case of ropes, tie-beams, king-posts, &c. 2. By *compression*, tending to shorten or crush the material ; as in columns, walls, and foundations. 3. By *transverse strain*, tending to break or bend the material ; as in beams, rails, and oars. 4. By *torsion* or twisting ; as in screws, rudders, and axles fixed to wheels. To these, Dr. Young has added another, viz., *detrusion* or pushing aside, as in the case of a pin or thread operated on by the blades of scissors. The changes called *flexure*, or bending ; *fracture*, or breaking ; and *alteration*, or permanent change of form without separation, are effects of force exerted on materials.

Resistance.—To these disturbing influences, bodies oppose certain qualities, which depend, in part, upon the nature of the material, and in part on its form, condition, and connection. These are, their *strength*, by which they resist all permanent changes resulting from mechanical force, but more particularly fracture. Their *hardness*, by which they resist impressions, or superficial changes. Their *stiffness*, by which they resist flexure or bending. Their *elasticity*, by which they regain their original size and form, after any force producing mechanical change in them has ceased to operate. Their *tenacity*, by which they undergo permanent alteration without fracture. This quality is called *ductility*, when exposed to extension, and *malleability*, when exposed to compression. Some authors add the term *resilience*, to express the quality by which a body resists impulse, like that of a blow, in contradistinction from strength, by which it resists pressure.

Extension.—When a bar of any material is drawn in the direction of its length, its resistance, or strength, will be proportionate to its size at the weakest point ; *i. e.*, to the area of its cross section at that point. The tie-beam of a roof, the posts of a printing press, and the shaft or piston rod of a pump, are exposed to this kind of strain ; and their weakest point is commonly found at the place where they are perforated, or mortised, to connect them with the other parts. Various experiments have been

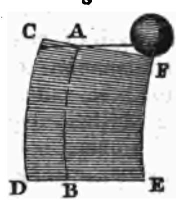
made to determine the comparative strength with which different substances resist extension. Although they do not fully agree in their results, they nevertheless, when taken collectively, afford approximations of some use for practical purposes. An idea of the relative strength of the metals, when extended, may be obtained from Mr. Rennie's experiments, detailed in the Philosophical Transactions for 1818. His experiments were made with bars, six inches long, and a quarter of an inch square. The average number of pounds avoirdupois, which they supported respectively, is in round numbers as follows. Steel, about 8000 pounds. Hammered iron, about 4000. Gun metal and wrought copper, 2000. Cast copper and brass, 1000. Tin, 300. Lead, 100. Experiments have been made on the longitudinal strength of the wood of different European trees; and similar experiments, sufficiently varied, on the trees of this continent, might be a valuable addition to our knowledge.

Compression.—When a bar or beam is compressed in the direction of its length, it resists more powerfully than in any other way. If the beam be long, and its strength be overpowered by pressure, it bends, and then breaks; but if its thickness be as much as a seventh part of its length, it commonly swells in the middle, splits, and is crushed. When a stone block or pillar is crushed, the parts nearest to the force break away, and slide off diagonally at the sides, leaving a pyramidal base. The lower stories of buildings, the piers and piles of bridges, the spokes of carriage wheels, and the legs of furniture, are subjects of this force. According to Mr. Tredgold, a cubic inch of malleable iron will support, without alteration, a weight of about 17,000 pounds; cast iron, 15,000; brass, 7000; oak and mahogany, nearly 4000; tin, 3000; lead, 1500. Granite is crushed by 11,000 pounds to the square inch; white marble, by 6000; Portland stone, by 4000.

When a force acts on a homogeneous straight column, in the direction of its axis, it can only extend or compress it equally through its whole substance. But if the direction of the force is not in the axis, but parallel to it,

the extension or compression will then be partial. In a rectangular column or block, when the compressing force is applied to a point more distant from the axis than one sixth of the depth, the remoter surface will be no longer compressed, but extended. In this case, the distance from the axis of the neutral point, or that which is neither compressed nor extended, will be inversely as that of the point to which the force is applied. For example, a weight or compressing force being applied on one side of the block or column CDEF, Fig. 1, and acting in a direction parallel to its axis, the compression will extend only to the line AB, the parts beyond this being extended.

Fig. 1.



Lateral strain.—When a beam is acted on transversely, or by a force applied to its side, the effect produced is the joint result of extension and compression. For if it be moved or bent by such a force, from its original direction, the part which becomes convex is extended, while the part rendered concave is compressed. The properties by which a beam resists lateral pressure, are, its stiffness and its strength.

Stiffness.—The stiffness of any substance is measured by the force required to cause it to bend or recede through a given small space in the direction of the force. It appears to be governed by different laws from those of the strength which resists fracture. When a force is applied to a beam transversely, its stiffness is directly as the breadth, and the cube of the depth of the beam, and inversely as the cube of its length.* Thus, if we have a

* Gregory's Mathematics for Practical Men, 389 ; also Young's Nat. Philosophy, i. 139, and Tredgold's Elements of Carpentry, 31.

beam which is twice as long as another, we must make it, in order to obtain an equal stiffness, either twice as deep, or eight times as broad. When a beam is supported at both ends, its stiffness is twice as great as that of a beam of half the length inserted in a wall, or otherwise firmly fixed, at one end. If both ends are firmly fixed, the stiffness is quadrupled.*

Tubes.—A tube or hollow beam is much stiffer than the same quantity, or weight, of matter in a solid form. The stiffness is increased nearly in proportion to the square of the diameter; since the cohesion and repulsion are equally exerted, with a smaller curvature, and act also on a longer lever. We see this principle applied in nature to the stems of reeds, and the bones and quills of animals.

Strength.—The strength of beams of the same kind, and fixed in the same manner, in resisting a transverse force which tends to break them, is simply as their breadth, as the square of their depth, and inversely as their length. Thus if a beam be twice as broad as another, it will also be twice as strong; but if it be twice as deep, it will be four times as strong; for the increase of depth not only doubles the number of the resisting particles, but also gives each of them a double power, by increasing the length of the levers on which they act. The increase of the length of a beam must obviously weaken it, by giving a mechanical advantage to the power which tends to break it; and some experiments appear to show, that the strength is diminished in a proportion greater than that in which the length is increased.

The strength of a beam supported at both ends, like

* The quantity of timber being the same, a beam will be stronger in proportion as the depth is greater; but there is a certain proportion between the depth and breadth, which, if it be exceeded, the beam will be liable to overturn and break sidewise. To avoid this, the breadth should never be less than that given by the following rule, unless the beam be held in its position by some other means.

Divide the length in feet, by the square root of the depth in inches, and the quotient multiplied by the decimal 0.6 will give the least breadth that should be given to the beam.—*Tredgold's Carpentry*, p. 32.

its stiffness, is twice as great as that of a single beam of half the length, which is fixed at one end; and if both the ends are firmly fixed, the strength of the whole beam is again doubled.

Place of strain.—If a weight or other stress be placed on any given point of a horizontal bar which is supported at both ends, the strain on that point will be proportional to the rectangle of the two segments into which the point divides the bar. Hence, the place where the strain would be greatest is in the middle of the bar, and a given weight would be most likely to break it in that place.

Incipient fracture.—An incipient or partial fracture, at the place of strain, weakens a beam more, than if the whole side of the beam were cut away to the same depth as the fracture. This is because the sound, or stronger parts of the beam tend to straighten themselves, and thus increase the curvature at the point which is weakened. The same cause occasions the breaking of glass in the direction of a cut made by a diamond, or of a crack which has commenced. It also explains the ease with which a bent twig may be cut off, if we begin on the convex or strained side. Mr. Emerson asserts that a triangular beam, which is so strained that the greatest extension takes place at one of its angles, is rendered stronger, rather than weaker, by cutting away this angle to a small depth, so as to convert the beam into a four-sided figure; thus producing the seeming paradox of a part being stronger than the whole. A sharp angle is indefinitely weak, and fracture is more likely to begin in an angle than in a broad surface.

Shape of timber.—It may be inferred from the consideration of the nature of the different kinds of resistance, that if we have a cylindrical tree a foot in diameter, which is to be formed into a prismatic beam by flattening its sides, we shall gain the greatest stiffness by making the breadth or thickness six inches, and the depth ten and a half; the greatest strength by making the breadth seven inches, and the depth nine and three quarters.

Torsion.—The kind of strain called torsion or twist-

ing, consists in the lateral displacement or detrusion of the opposite parts of a solid, in opposite directions; the central particles only remaining in their natural state. The strength, or rather stiffness, with which the shaft of a wheel, or crank resists torsion, increases in a rapid ratio to its diameter. Professor Robison has calculated, that the power of resisting torsion is as the cube of the diameter; and the more recent estimates of M. Duleau make it as the fourth power of the diameter. If the length vary, the resistance to the force of torsion will be inversely as the length, for obvious reasons. It is advantageous in machinery to increase the diameter of shafts which are exposed to this strain, the amount of material remaining the same. For this purpose, they are sometimes made hollow, and sometimes winged with lateral projections.

Limit of bulk.—It is important to recollect that when the bulk of a substance employed becomes very considerable, its own weight may bear so great a proportion to its strength, as to add materially to the load to be supported. In most cases, the weight of bodies increases more rapidly than their strength, and thus causes a practical limitation of the magnitude of our machines and edifices. Thus a roof, or a bridge, may be very strong, when of small, or moderate size; but if the size be extended beyond a certain limit, although the materials and proportion of parts remain the same, yet the structure will not support its own weight. We see also a similar limit in Nature; for if trees and animals were made many times larger than we now find them, and of the same kinds of substance, they would not sustain their own weight. Small animals endure greater comparative violence, and perform greater feats of strength in proportion to their size, than large ones. It has been observed that whales are larger than any land animals, because their weight is more equally supported by the pressure of the medium in which they swim.

Practical Remarks.—In frames of houses, and for various other purposes, beams are used of a prismatic form, having straight, parallel sides. But such beams, when

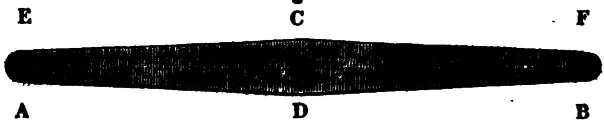
exposed to a lateral strain, are not of equal, or duly proportioned strength throughout; and therefore a part of them is superfluous. This consideration is not of much importance in ordinary practical cases. But in cases where economy of the material is important, as in cast-iron rail-roads, also in machinery where it is desirable that the moving parts should be as light as possible, consistently with the requisite strength, it becomes of consequence to ascertain the best form for resisting a force with the smallest amount of material. Mathematicians have calculated the forms of different beams, which are suited to give them, at all points, a strength proportionate to the pressure they sustain, supposing the material to be of uniform texture. But the outline which answers merely to mathematical truth, is, in many cases, too scanty for actual employment; so that in order to obtain sufficient length for a secure connexion of the beam with its bearings, it is necessary to include the mathematical figure in a somewhat similar one, of larger dimensions. The following rules are, most of them, given in substance by Mr. Tredgold.

If a beam be supported at both ends, and a load applied at some one point between the supports, and always pressing downwards, the best plan appears to be, to make the under side, or that opposite the load, perfectly straight; and to make the breadth equal throughout the whole. The upper side should be shaped as in Fig. 2, being highest where the load rests.

Fig. 2.

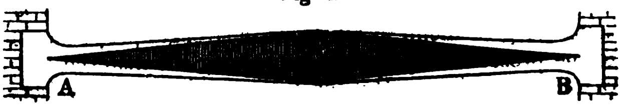
The same form is proper for a beam supported in the middle, as the beam of a balance. If the beam be strained, sometimes from one side and sometimes from the other, as in the beam of a steam-engine, then both sides should be of the same form, and EA and FB should each be equal to half CD, as in Fig. 3.

Fig. 3.



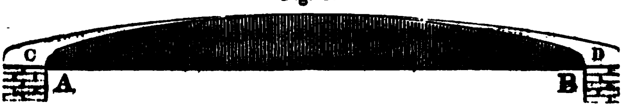
If a beam be of equal thickness, and a weight, or force, be applied to its flat side, the shape may be such as is represented in Fig. 4.

Fig. 4.



If a beam be intended to support a weight uniformly distributed throughout its length, or a load rolling over it, the line bounding the compressed side should be a half-ellipse, the other side being straight, as in Fig. 5.

Fig. 5.



Where it is necessary that the upper side should be straight, the above form may be inverted, and the ends adapted to the bearings.

Beams which are fixed at one end only, and support weights, should decrease as they recede from the wall, or point of fixture. If the weight be at the extremity, the outline, in a beam cut from a vertical plank, should be parabolic; but if equally distributed throughout, it may be straight.

Fig. 6.

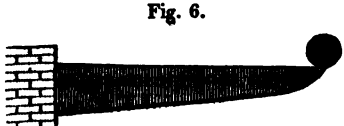
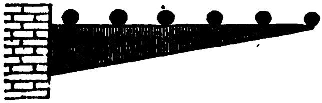
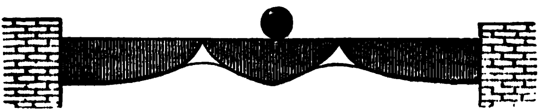


Fig. 7.



If a beam be firmly fixed at both ends, and supports a weight in the middle, it should be largest at the ends and in the middle, as in Fig. 8.

Fig. 8.



For resisting a cross strain, it is advantageous that the edges of a beam should be made thicker than the rest of its substance, so that a section of the beam would be nearly such as is seen in the subjoined figure.*

Fig. 9.

When it is designed that a shaft should be stiff in all directions, it should be tubular, or else ribbed on all sides.

It must be recollected that the foregoing rules prescribe only a general form, the proportions of which must vary with the nature of the material, and the degree of resistance, or load to be supported.

Works which treat of the strength of materials.—ROBISON'S Mechanical Philosophy, 4 vols. 8vo. 1822, vol. i. p. 369, &c.;—BARLOW on Timber, 8vo. 1823;—YOUNG'S Natural Philosophy, 2 vols. 4to. 1807; vol. i. p. 135, &c.; vol. ii. art. 333, &c.;—RENNIE, in the Philosophical Transactions, 1818;—DULEAU, *Annales de Chimié*, tom. xii.;—TREDGOLD'S Elementary Principles of Carpentry, 4to. 1820;—TREDGOLD'S Essay on Cast Iron, 8vo. 1824;—EMERSON'S Mechanics;—GREGORY'S Mechanics, 3 vols. 8vo. edit. 1826;—GREGORY'S Mathematics for Practical Men, 8vo. 1825.

* For the form best suited to resist longitudinal pressure, see the article *Column* in Chap. VII.

CHAPTER IV.

OF THE PRESERVATION OF MATERIALS.

Stones, Metals, Organic Substances, Temperature, Dryness, Wetness, Antiseptics. Timber—Felling, Seasoning. Preservation of Timber. Preservation of Animal Textures—Embalming, Tanning, Parchment, Catgut, Goldbeater's Skin. Specimens in Natural History—Appert's Process.

Stones.—Most of the stones and other minerals employed for purposes requiring strength, are sufficiently incorruptible to last for ages, without requiring any particular protection from the chemical agency of the atmosphere. The granite and marble of some of the oldest Grecian and Roman structures retain their smoothness at the present day. Bricks and terra cotta are equally indestructible. Nevertheless, it sometimes happens that the strongest rocks become disintegrated in time, and fall to pieces, in consequence of their containing iron pyrites, or some other substance, upon which chemical action easily takes place. This defect is observed in some varieties of sienite and of freestone. A rock should always be rejected in building, which in its natural situation is found to be soft and friable at its surface, however hard its interior may be. Sometimes the surface of buildings is found to be disfigured by the oxidation of iron, in spots or streaks, upon the stone. The only remedy, where corruptible materials of this sort have been used, appears to consist in keeping them covered with a coating of paint, sufficient to exclude air and moisture.

Metals.—The precious metals, as gold, silver, and platina, being incapable of oxidation under common circumstances, require no process to keep them from decay. But many other metals become speedily corroded by exposure to the air and moisture, and require an artificial surface to protect them from decay. Copper protects itself by forming, when exposed to the atmosphere, a su-

perficial coating of carbonate of copper, which gives it a dark color, but prevents the further action of the air on the internal parts. It is from this cause that the copper coins and the bronze statues and ornaments of antiquity remain nearly unimpaired at the present day. But the most useful of all metals, iron, is speedily rusted by exposure to the weather, and pure malleable iron decays more rapidly than cast iron. A mass of iron filings is speedily converted, by druggists, into carbonate of iron, by causing a small quantity of water to trickle gradually through it, the air being also admitted. Some curious facts are attendant on the rusting of iron. If a bar of this metal be frequently agitated, it rusts apparently much less, than a similar bar at rest in the same place. This fact is observed in rail-roads, and is noticed by Mr. Wood, in his treatise. A polished surface resists the action of the atmosphere longer than a rough surface, because less of the metal comes in contact with the air. Certain galvanic combinations are found to retard the chemical change, or decay, of metals. Sir Humphrey Davy discovered that the copper sheathing of ships may be preserved from corrosion or decay, by placing over it bars of some oxidable metal, such as lead, zinc, and especially cast iron. But in vessels thus guarded, although the copper remained entire, yet the bottoms became exceedingly foul by the adhesion of seaweed, shells, and marine animals. It is probable that these living beings are kept off by the poisonous nature of the copper, which becomes operative only when the metal is oxidated or corroded, and that, therefore, the usefulness of the copper depends upon its decaying.

To prevent the corroding and tarnishing of metals, it is customary, in the arts, to cover them with some less destructible material which may exclude the air. The more permanent metals, such as gold, silver, and tin, are applied to protect those which are less permanent, and hence have arisen the arts of gilding, plating, and tinning. Large and coarse objects are generally protected by a coating of paint, varnish, or oil, as in iron railings and large machinery. A valuable varnish for iron is made

from coal tar. Where the lustre of a polished metal is intended to be preserved, a transparent varnish, or lacker, is employed. Rubbing, or scouring, is a temporary, though often necessary expedient, which removes a dull surface, at the expense of wearing out the material.

When cast iron is buried in the earth, especially if imbedded in clay, its decay is extremely slow, as is seen in aqueducts and gas pipes made of this material.

Organic substances.—The compounds which are spontaneously formed by organic bodies, both vegetable and animal, are of a different nature from those which exist in unorganized matter. They are the peculiar results of vital processes, and neither their structure nor composition can be imitated by art. During life, the elements of organic bodies are held together by vital affinities, under the influence of which they were originally combined. But no sooner does life cease, than these elements become subject to the laws of inert matter. The original affinities, which had been modified, or suspended, during life, are brought into operation; the elementary atoms react upon each other, new combinations are formed, and the organized structure passes sooner or later into decay.

The rapidity with which decomposition takes place in organic bodies, depends upon the nature of the particular substance, and upon the circumstances under which it is placed. Temperature, moisture, and the presence of decomposing agents, greatly affect both the period and extent of this process. By regulating, or preventing, the operation of these causes, the duration of most substances may be prolonged, and many materials are rendered useful, which, if left to themselves, would be perishable and worthless. The preservation of timber, of fibrous substances, of leather, of food, and of various objects of art, are subjects of the highest importance, and have received, at various times, much attention from scientific experimentalists.

Temperature.—The influence of temperature, in accelerating or retarding the decay of organized substances, is generally known. Cold tends to check the progress of destructive fermentation, and when it extends so far as to

produce congelation, its preservative power is complete. Bodies of men and animals have been found frozen, in situations where they had remained for years, and even ages; and the recent discovery of an extinct species of elephant, in the ice of Siberia, shows that the period of this preservation is unlimited. On the other hand, in warm seasons and in hot climates, every thing tends to corruption and decay. Both animal and vegetable substances pass rapidly into the putrefactive fermentation; alimentary substances are difficult to preserve, and when moisture is combined with heat, ships, houses, and other structures of wood, as well as cordage, canvass, and clothing, have the period of their duration greatly abridged.

Dryness.—Although certain degrees of heat, especially when combined with moisture, tend greatly to promote decomposition, yet if the degree of heat, and the circumstances under which it acts, are such as to produce a perfect dissipation of moisture, the further progress of decay is arrested. The exertion of chemical affinities usually requires that one of the agents at least should be in a fluid state. And while a body is in a state of perfect dryness, no internal chemical change is likely to befall it. The beams and furniture of houses, often remain entire for centuries. In the arid caverns of Egypt, the wood of sarcophagi appears to have undergone no alteration in the lapse of two or three thousand years; the fibres of linen textures are found distinct and perfect, though weakened in strength, and the dried flesh of the mummies themselves discovers no marks of decomposition. In cabinets of Natural History, the specimens, so long as they are kept perfectly dry, undergo no alteration from spontaneous decay. They are, however, extremely liable to the depredations of insects, from which they require to be protected, either by impregnating them with poisonous substances, or by enclosing them in cases which are hermetically tight. In damp seasons and situations, an artificial dryness may be produced by keeping a shallow vessel of quicklime within the cases, and renewing it as fast as it becomes saturated.

Wetness.—Some materials, especially wood, are capable of lasting for a long time, if kept continually im-

mersed in water, especially at low temperatures. Thus the lower part of a pump log is much more durable than the upper, if kept always under water. The effect of pure water is to dissolve and carry off the soluble parts, leaving the fibrous structure in a state less liable to fermentation than before. Some animal substances, likewise, such as leather, bear immersion in water for a considerable time. It must be observed, however, that the effect of wetness upon most organized bodies, is to soften their texture, and render them less able to support mechanical violence, than when dry. Wood, after having been long immersed, if taken out and dried, is found to be more brittle than it was before.

But the state which most rapidly promotes decay, is that of alternate moisture and dryness, attended with exposure to the atmospheric air. It appears, in regard to wood, that in each wetting, a sensible portion of substance is dissolved, and that in each drying, a new portion of soluble matter is formed. In a ship, under common circumstances, the parts which first decay, are those which are situated between wind and water, or are subjected to alternate dryness and moisture. So also in a post standing in the earth, the part which first decays, is usually that which is nearest the surface of the ground. Exposure to the vicissitudes of weather, is also one of the most common and active causes of decomposition.

Antiseptics.—A certain class of substances has received the name of antiseptics, from their power, when present, of resisting putrefaction in organic bodies, as well as in their products. Such are charcoal, tannin, resins, camphor, bitumen, sugar, chlorine, alcohol, oils, acids, and salts of various kinds. The manner in which they exert their preservative agency is not fully understood. It abpears, however, that in some cases they combine with the substance to be preserved, forming a less perishable compound, as in the instance of leather; and probably in other instances they unite with and qualify the decomposing agents which are present.

Timber.—A vast expense is every year created by the premature decay of wood, employed in ships and

other structures, which are exposed to vicissitudes of weather, and especially if they are subjected to the influence of warmth combined with moisture. Trees of different species, vary greatly in the durability of their wood, yet none of the species commonly employed, are capable of withstanding, for many years, the effect of unfavorable exposures and situations. The decay in timber is sometimes superficial, and sometimes internal. In the former case, the outside of the wood first perishes and crumbles away, and successive strata are decomposed, before the internal parts become unsound. In the other species, which is distinguished by the name of the *dry rot*, the disease begins in the interior substance of the wood, particularly of that which has not been well seasoned, and spreads outwardly, causing the whole mass to swell, crack, and exhale a musty odor. Different fungous vegetables sprout out of its substance, the wood loses its strength, and crumbles finally into a mass of dust. This disease prevails most in a warm, moist, and confined, atmosphere, such as frequently exists in the interior of ships, and in the cellars and foundations of houses. Its destructive effects, in ships of war, have given rise to numerous publications. Some writers consider that the dry rot is not essentially different from the more common kinds of decay, but there seems to be sufficient reason for the distinction which has usually been drawn. The prevention of the evil has been attempted in various ways, and with some degree of success.

Felling.—It is agreed, by most writers, that the sap of vegetables is the first cause of their fermentation and decay. Hence it appears desirable, if there is any season, in which the trunk of a tree is less charged with sap than at others, that this time should be selected for felling it. The middle of summer and the middle of winter, are undoubtedly the periods when the wood contains least sap. In the months of spring and fall, in which the roots prepare sap, but no leaves exist to expend it, the trunk is overcharged with sap ; and in many trees, as the maple and birch, sap will flow out at these seasons, if the trunk is wounded. In summer, on the contrary, when the leaves are out, the

sap is rapidly expended, and in winter, when the roots are dormant, it is sparingly produced; so that no surplus of this fluid apparently exists. From reasoning *a priori*, it would seem that no treatment would be so effectual in getting rid of the greatest quantity of sap, as to girdle the tree, by cutting away a ring of alburnum, in the early part of summer, thus putting a stop to the further ascent of the sap, and then to suffer it to stand until the leaves should have expended, by their growth, or transpiration, all the fluid which could be extracted by them previously to the death of the tree. The wood would thus probably be found in the driest state to which any treatment could reduce it in the living state. Buffon has recommended stripping the trees of their bark in spring, and felling them in the subsequent autumn. This method is said to harden the alburnum, but the cause is not very apparent, nor is the success at all certain.

Seasoning.—At whatever period timber is felled, it requires to be thoroughly seasoned, before it is fit for the purposes of carpentry. The object of seasoning is partly to evaporate as much of the sap as possible, and thus to prevent its influence in causing decomposition; and partly to reduce the dimensions of the wood, so that it may be used without inconvenience from its further shrinking. Timber seasons best, when placed in dry situations, where the air has a free circulation round it. Gradual drying is considered a better preservative of wood, than a sudden exposure to warmth, even of the sun; for warmth abruptly applied, causes cracks and flaws from the sudden and unequal expansion produced in different parts. Two or three years' seasoning is requisite to produce tightness and durability in the wood work of buildings. It must be observed, that seasoning in the common way only removes a portion of the aqueous and volatile matter from the wood. The extractive and other soluble portions still remain, and are liable to ferment, though in a less degree, whenever the wood reabsorbs moisture. Such, indeed, is the force of capillary attraction, that wood, exposed to the atmosphere in our climate, never gives up all its moisture. Seasoning by stove heat, in buildings constructed for

the purpose, has been found to answer well, and to save much time, especially in boards partly seasoned before.

Preservation of Timber.—When wood is to be kept in a dry situation, as in the interior of houses, no other preparation is necessary than that of thorough seasoning. But when it is to be exposed to the vicissitudes of weather, and still more when it is to remain in a warm and moist atmosphere, its preservation often becomes extremely difficult. Numerous experiments have been made, and many volumes written, upon the preservation of timber, and the prevention of the dry rot; but the subject is not yet brought to a satisfactory conclusion. The methods which have hitherto been found most successful, consist in extracting the sap, in excluding moisture, and in impregnating the vessels of the wood with antiseptic substances.

For extracting the sap, the process of *water seasoning* is recommended. It consists in immersing the green timber in clear water for about two weeks; after which, it is taken out and seasoned in the usual manner. A great part of the sap, together with the soluble and fermentable matter, is said to be dissolved or removed, by this process. Running water is more effectual than that which is stagnant. It is necessary that the timber should be sunk, so as to be completely under water, since nothing is more destructive to wood, than partial immersion. Mr. Langton has proposed to extract the sap by means of an air-pump, the timber being enclosed in tight cases, with a temperature somewhat elevated, and the sap being discharged in vapor by the operation of the pump.

It appears extremely probable, that if trees were felled in summer, and the buts immediately placed in water, without removing the branches, a great part of their sap would be expended by the vegetative process alone, and replaced by water. It is well known that branches of plants, if inserted in water, continue for some days to grow, to transpire, and to perform their other functions. This they probably do at the expense of the sap, or assimilated fluid, which was previously in them, while they replace it by the water they consume. This state of

things continues until the juices are too far diluted to be capable of any longer sustaining life.

The *charring* of timber by scorching, or burning its outside, is commonly supposed to increase its durability, but on this subject the results of experiment do not agree. Charcoal is one of the most durable of vegetable substances; but the conversion of the surface of wood into charcoal, does not necessarily alter the character of the interior part. As far, however, as it may operate in excluding worms, and arresting the spreading of an infectious decay, like the dry rot, it is useful. Probably, also, the pyroligneous acid which is generated when wood is burnt, may exert a preservative influence.

The exclusion of moisture, by covering the surface with a coating of paint, varnish, tar, &c., is a well-known preservative of wood which is exposed to the weather. If care is taken to renew the coat of paint, as often as it decays, wood, on the outside of buildings, is sometimes made to last for centuries. But painting is no preservative against the internal or dry rot. On the contrary, when this disease is begun, the effect of paint, by choking the pores of the wood, and preventing the exhalation of vapors and gases which are formed, tends rather to expedite, than prevent the progress of decay. Paint, itself, is rendered more durable, by covering it with a coating of fine sand. Wood which is not thoroughly seasoned, should never be painted.

The impregnation of wood with tar, bitumen, and other resinous substances, undoubtedly promotes its preservation. It is the opinion of some writers, that "woods abounding in resinous matter, cannot be more durable than others," but the reverse of this is proved every year in the pine forests of this country, where the *lightwood,* as it is called, consisting of the knots and other resinous parts of pine trees, remains entire, and is collected for the purpose of affording tar, long after the remaining wood of the tree has decayed. A coating of tar or turpentine, externally applied to seasoned timber, answers the same purpose as paint in protecting the wood, if it is renewed with sufficient frequency. Wood impregnated with drying oils,

such as linseed oil, becomes harder and more capable of resisting moisture. It is frequently the practice, in this country, to bore a perpendicular hole in the top of a mast, and fill it with oil. This fluid is gradually absorbed by the vessels of the wood, and penetrates the mast to a great distance. Animal oils, in general, are less proper for this purpose, being more liable to decomposition.

The preservative quality of common salt (muriate of soda) is well known. An example of its effect is seen in the hay of salt marshes, which is frequently housed before it is dry, and which often becomes damp afterwards from the deliquescence of its salt, yet remains unchanged for an indefinite length of time. In the salt mines of Poland and Hungary, the galleries are supported by wooden pillars, which are found to last unimpaired for ages, in consequence of being impregnated with the salt, while pillars of brick and stone, used for the same purpose, crumble away in a short time by the decay of their mortar. Wooden piles, driven into the mud of salt flats and marshes, last for an unlimited time, and are used for the foundations of brick and stone edifices. In canals, which have been made in the salt marshes about Boston and other places, trunks of oak trees are frequently found with the heart wood entire and fresh, at a depth of five or six feet below the surface. At Medford, Mass., the stumps of trees are found standing in the gravelly bottom of the salt marsh where the tide rises in the canals four or five feet above them. This bottom must originally have constituted the surface of the ground, and must have settled long enough ago for the marsh mud to have accumulated, as it has done for miles round, apparently since that period.

The application of salt in minute quantities, is said rather to hasten than prevent the decay of vegetable and animal bodies. Yet the practice of *docking* timber, by immersing it for some time in sea-water, after it has been seasoned, is generally admitted to promote its durability. There are some experiments which appear to show, that after the dry rot has commenced, immersion in salt water effectually checks its progress, and preserves the remain-

der of the timber.* In some of the public ships built in the United States, the interstices between the timbers in various parts of the hull, are filled with dry salt. When this salt deliquesces, it fills the pores of the wood with a strong saline impregnation, but it has been said, in some cases, to render the inside of the vessel uncomfortably damp. If timber is immersed in a brine made of pure muriate of soda, without the bitter deliquescent salts which sea-water contains, the evil of dampness is avoided.

A variety of other substances, besides common salt, act as antiseptics, in preventing the dry rot, and the growth of the fungus which attends it. Nitre and alum have been recommended for this purpose, and some of the metallic salts are considered still more effectual. Of these, the sulphates of iron, copper, and zinc have the effect to harden and preserve the timber. Wood boiled in a solution of the former of these, and afterwards kept some days in a warm place to dry, is said to become impervious to moisture. Lime-water has recently been found a powerful antiseptic. Corrosive sublimate, as recommended by Sir H. Davy, is perhaps the most powerful preservative of organized substances from decay, and proves destructive to parasitic vegetables and animals; but its safety, in regard to the health of crews, if used in large quantities about the wood of a ship, may be considered as doubtful.

An opinion has been supported in this country, that the decay of timber in ships, by dry rot, is owing to the impure atmosphere generated by bilge water, and that it is to be remedied by constructing ships with a view to their free and effectual ventilation.

Preservation of Animal Textures.—The solid and fibrous portions of organic bodies, such as wood, bone, shell, horn, hair, cotton, &c., are most easy of preserva-

* The British frigate Resistance, which went down in Malta harbor, and the Eden, which was sunk in Plymouth Sound, were both affected with dry rot. These ships, after remaining many months under water, were raised, and it was found that the disease was wholly arrested. Every vestige of fungus had disappeared, and the ships remained in service afterwards, perfectly sound from any further decay.—*Supplement to the Encyclopedia Britannica*, iii. 682.

tion. But the soft and succulent parts, such as the pulp of vegetables, and the flesh of animals, are extremely perishable, owing to the decomposing influence of their fluid contents; and require the assistance of art to communicate to them any degree of durability. These substances, when they cannot be dried, are usually preserved by enveloping or impregnating them with antiseptics. For alimentary substances the antiseptics used are sugar, alcohol, salt, and the acetous and pyroligneous acids; while, for scientific specimens and preparations, alcohol, oil of turpentine, resinous and bituminous varnishes, alum, and corrosive sublimate, are found most effectual.

Embalming.—As the art of embalming can hardly be ranked among the useful arts, any further than it can be made subservient to the promotion of anatomy, or natural history, it is not much cultivated at the present day. The ancient Egyptians converted the dead bodies of their friends into mummies, by removing the viscera from the large cavities, and replacing them with aromatic, saline, and bituminous substances, particularly asphaltum; and also enveloping the outside of the body in cloths impregnated with similar materials. These impregnations prevented decomposition, and excluded insects, until perfect dryness took place. In times comparatively modern, embalming has been practised with great success, particularly where bodies have remained at a low and uniform temperature, and have been protected from the access of the air. The body of King Edward the First, of England, appears upon record to have been embalmed. He died in July, 1307, and was buried in Westminister Abbey. In 1770, his tomb was opened, and the contents examined, and after this lapse of four hundred and sixty-three years, the body of the monarch remained entire. The flesh upon the face was a little wasted, but not putrid. The body of Canute, King of Denmark, who invaded England in 1017, was found very fresh in 1776, by the workmen employed in repairing Winchester Cathedral. The bodies of William the Conqueror, and of Matilda his wife, both buried at Caen, were found entire in the sixteenth century. In like manner, the remains of various other princes, and

persons of note, have been discovered to be undecayed some centuries after their decease. In certain cases, bodies not embalmed have been preserved, merely by the exclusion of air, and a uniform, low temperature.

But the most perfect of all the modes of preserving the animal body, without continued immersion, appears to be, a thorough impregnation with corrosive sublimate. This may be performed, by saturating the soft solids with a strong solution, consisting of about four ounces of bichloride of mercury to a pint of alcohol. This is injected into the blood-vessels, and after the viscera are removed, the whole body is immersed for three months in the same solution. At the end of this period, it easily dries, and is afterwards nearly imperishable.

In what are called by anatomists *wet preparations*, the objects are kept immersed in alcohol, and last for an indefinite time. Oil of turpentine answers the same purpose, and in the Museum of Natural History in Paris, there is a head prepared in this way, more than a hundred years ago, by the celebrated Ruytch, which preserves all the vivacity of its colors. In cold weather, the liquid becomes opaque, but is again rendered transparent in the spring.

An artist at Florence is said to have discovered a mode of petrifying animal substances, but his method has not been communicated to the world.

Tanning.—The skins of animals, when prepared by merely drying them, are stiff, incapable of resisting water, and liable to decay. If, however, they are impregnated with the *tannin* which is found in astringent vegetables, that substance combines with the gelatin of the skin, and forms a durable compound, which is no longer soluble in water. Common tanned leather is prepared in this way. The skins are previously prepared by soaking them in lime-water, which facilitates the separation of the cuticle and hair. A slight degree of putrescency assists the same object. They are then immersed in the tan-pits, in a strong infusion of some astringent vegetable. Oak bark, from its cheapness, and the quantity of tannin it contains, is commonly employed in the preparation of leather, both

in this country, and in Europe. The bark of the hemlock spruce, and of the chestnut, the leaves of the different species of sumach, and various other astringent vegetables, are used in sections of country where oak is scarce. The strength of the astringent infusion is increased from time to time, until the skin is saturated with tannin. A portion of extractive matter likewise combines with the hide, and to this the brown color, which is common in leather, is owing. The presence of this extractive is supposed to render leather more tough and pliable.

When strong or saturated solutions of tannin are used, the leather is formed in a much shorter time, but it is observed that leather tanned in this way is more rigid and more liable to crack, than that made in the common manner, with weaker infusions, gradually increased in strength. But sole leather, the most important requisites of which are firmness and resistance to water, is immersed in an infusion kept nearly saturated by alternate strata of bark. The full impregnation requires from ten to eighteen months.

The *currying* of leather is performed by covering the skin or leather, while yet moist, with common oil, which, as the moisture evaporates, penetrates into the pores of the skin, giving it a peculiar suppleness, and rendering it, to a certain extent, water proof. During the process, it is pared, washed, and rubbed, to increase its flexibility. The black color is also imparted by the currier, by rubbing the outside with a solution of copperas, or any solution of iron, which immediately turns it black, by combining with the tannin in the leather.

Tawing is the method by which skins are dressed of a white color, and it is performed without the use of bark. The skins are first prepared by steeping them in lime-water, and subjecting them to various processes of scraping and fulling. They are then fermented with wheat bran, and afterwards impregnated with a solution of alum and common salt. Before being dried, they are fulled with wheat bran and yolks of eggs, and are thoroughly trodden, steeped, and washed. In this process, the place of tannin appears to be supplied by some principle extracted from the alum.

As examples of the foregoing processes, common sole leather is simply *tanned*, the upper leather of boots and shoes is *tanned* and *curried*, the white leather for gloves is *tawed*, and fine morocco leather is *tawed*, and afterwards slightly *tanned* with sumach, and dyed. *Chamois*, and other kinds of *wash leather*, are steeped in lime pits, and afterwards fulled with oil. Before the dressing is finished, the superfluous oil is scoured out with an alkaline liquor.

Parchment.—Parchment used for writing, is prepared from the skins of sheep and goats. These, after being steeped in pits impregnated with lime, are stretched upon frames, and reduced by scraping and paring, with sharp instruments. Pulverized chalk is rubbed on with a pumice stone resembling a muller, which smooths and softens the skin, and improves its color. After it is reduced to something less than half its original thickness, it is smoothed and dried for use. *Vellum* is a similar substance to parchment, made from the skins of very young calves.

Catgut.—The strings of certain musical instruments, the cords of clock weights, and those of some other machines and implements, are made of a dense, strong, animal substance, among us usually denominated *catgut*. It is derived from the intestines of different quadrupeds, particularly those of cattle and sheep. The manufacture is chiefly carried on in Italy and France. The texture from which it is made, is that which anatomists call the *muscular* coat, which is carefully separated from the peritoneal and mucous membranes. After a tedious and troublesome process of steeping, scouring, fermenting, inflating, &c., the material is twisted, rubbed with horsehair cords, fumigated with burning sulphur, to improve its color, and dried. Cords of different size, and strength, and delicacy, are obtained from different domestic animals. The intestine is sometimes cut into uniform strips with an instrument made for the purpose. To prevent offensive effluvia during the process, and to get rid of the oily matter, the French make use of an alkaline liquid called *eau de Javelle*.

Goldbeaters' Skin.—This delicate membrane is also

manufactured from the intestines of animals. The workman strips off that part of the peritoneal membrane which surrounds the *cæcum*. He then takes about two feet of it in length, turns it inside out, and leaves it to dry. It is afterwards steeped in a weak solution of potash, cleansed by scraping, and cut open. It is then stretched to dry upon wooden frames, and notwithstanding the tenuity of the membrane when dry, every piece of it is double or consists of two membranes glued together. It is finished by washing it with a solution of alum, and coating it with isinglass and whites of eggs, together with some aromatics to repel insects.

Specimens in Natural History.—Preparations of animals intended to show their external form and characters, are made by detaching their skins, and stuffing or mounting these so as to represent the natural figure and attitudes of the animal. Quadrupeds and birds are preserved by extracting the body through an opening on the under side, at the same time inverting the skin. The fleshy parts of the limbs are extracted through the same opening, also the neck, brain, and eyes, leaving the scull, if the animal be small. Care is taken not to injure the hair, or plumage. When the fleshy parts are removed, the inside of the skin is rubbed with some poisonous substance, usually arsenic,* to destroy insects. The skin is then returned to its natural situation, and filled with cotton or tow; or, what is still better, an artificial body, shaped out of wood, cork, or dried clay, may be introduced within the skin. The opening is sewed up, and wires are passed longitudinally through the legs and neck. These are afterwards bent into the proper position to give the attitude desired. Glass eyes are inserted, and the hair and feathers rendered as smooth as possible, and retained, while drying, in paper bandages.

Reptiles, and fishes without scales, are extracted by carefully separating the bones of the neck through an open-

* The following is the *arsenical soap* of Becœur, much used in France: Camphor, five ounces; powdered arsenic, two pounds; white soap, two pounds; salt of tartar, twelve ounces; lime, four ounces, melted and triturated together.

ing in the throat, or gills, and inverting the skin. In serpents, the whole body is easily extracted through the mouth. Fishes with scales cannot be turned without injury; it is therefore necessary to detach the skin carefully, without doubling it. Insects may be killed, without hurting their texture, by the fumes of burning sulphur, or prussic acid, or, in many cases, by pinching the breast. They are then secured by pins, and placed to dry with the wings and legs in the natural attitudes. Arsenic, or corrosive sublimate, is generally necessary to secure them from the depredations of other insects.

An Herbarium, or collection of dried plants, is usually formed by subjecting the plants, while fresh, to a sufficient pressure between folds of paper, to preserve their natural smoothness and regularity, until they become dry. The plants should be gathered at a time when their characters are most perfectly developed. A specimen in flower should be preserved, and, if possible, one also in fruit. The plant must be carefully spread out on smooth bibulous paper, so that the leaves, petals, &c., may be displayed as perfectly as possible. In this situation it is retained, and another sheet of paper turned gradually over it, commencing at one side, till the whole is covered. Several sheets of paper are then to be added to each side, and the whole placed to dry under a strong, equal pressure. In this way many plants may be preserved without further trouble, especially if the weather be warm and dry. The process, however, may be expedited by shifting the papers, or by passing over them occasionally a warm iron. These precautions are more necessary for succulent plants, or for others in cold and damp weather.

Appert's Process.—A method brought into notice by M. Appert, for preserving articles of food unchanged for several years, deserves to be noticed among the practical improvements of the present century. This method was partially known at a much earlier period, but its most successful modes of application were undoubtedly discovered by M. Appert. It consists in a very simple process. The articles to be preserved are enclosed in bottles, which are filled to the top with any liquid; for

example, with the water in which the article, if solid, has been boiled. The bottles are closely corked, and cemented, to render them hermetically tight. They are then placed in kettles filled with cold water, and subjected to heat till the water boils. After the boiling temperature has been kept up for a considerable time, in some cases an hour, but varying with the character of the article to be preserved, the bottles are suffered to cool gradually. In this state, meats, vegetables, fruits, milk, and other substances, are preserved perfectly fresh, without any condiments, for long periods, of from one to six years. Instead of bottles, tin canisters are sometimes used, and rendered tight by soldering.

The remarkable effect of this process has been explained, by attributing the preservation of the articles to the total exclusion of atmospheric air. But as air, in common cases, is always present in sufficient quantities to excite fermentation, it is supposed that the application of heat serves to fix the small portion of atmospheric oxygen which is present, by combining it with some principle in the other substances; so that it is no longer capable of producing the fermentative action, which in parallel cases leads to decomposition.

WORKS OF REFERENCE.—CHAPMAN's Treatise on the Preservation of Timber, 8vo. 1817;—TREDGOLD's Elementary Principles of Carpentry, 4to. 1820;—McWILLIAM, on the Dry Rot, 4to. 1818;—Article *Dry Rot*, in the supplement to the Encyclopedia Britannica; —AIKEN's Chemical Dictionary, article *Leather*;—LABARRAQUE, *l'Art du Boyaudeur; Bulletin, de la Société de l'Encouragement pour l'Industrié*, 1822;—LETTSOM's Naturalist's Companion, 8vo.; —Taxidermy, or the Art of Collecting, Preparing, and Mounting Specimens in Natural History, London, 1823;—APPERT, Art of Preserving Animal and Vegetable Substances, London, translated, 1812;—Edinburgh Review, vol. xxiii. p. 104;—URE's Dictionary of Arts, article *Putrefaction*.

CHAPTER V.

OF DIVIDING AND UNITING MATERIALS.

Modes of Division.—Fracture, Cutting, Cutting Machines, Planing Machines, Penetration, Boring and Drilling, Mortising, Turning, Attrition, Sawing, Saw Mill, Circular Saw, Dovetailing, Crushing, Stamping Mill, Bark Mill, Oil Mill, Sugar Mill, Cider Mill, Grinding, Grist Mill, Color Mill. Modes of Union.—Insertion, Interposition, Binding, Locking, Cementing, Glueing, Welding, Soldering, Casting, Fluxes, Moulds.

The attraction of cohesion, which retains together the particles of solid bodies, is the foundation of their strength. It exists in all solids, though in different degrees; and requires, before it can be overcome, the application of force or of art, adapted to the strength and character of the particular body. In some substances, cohesion, when once overcome, cannot be reproduced in its original state. In others, it may be restored by the intervention of fluidity, and in all, its effects may be imitated by mechanical arrangements. The various modes by which bodies may be divided, or united, have an important agency in mechanical constructions, and other processes of art.

MODES OF DIVISION.

Fracture.—The simplest and least artificial mode by which mechanical division is effected, is by breaking. The circumstances which influence the production of fracture by extension, compression, lateral strain, and torsion, have been considered in the third chapter of this work. In general, a force acting suddenly is more liable to occasion fracture, than one which acts more gradually; for in this case, the parts which are first strained may give way, before the stress is proportionally distributed among the remaining parts. A mass of plastic clay, or of warm sealing wax, will bear to be gradually bent, but will break if the motion is sudden. In like manner, percussion occasions fracture more readily than

pressure. A crack, or partial fracture, in a body, greatly promotes the separation of the remainder, whenever a lateral force is applied; because the strength of the sound parts tends to throw the strain more immediately upon the weakened points, as explained on page 125. In stone quarries, regular blocks are split out by driving rows of wedges in a straight line, so as to produce a simultaneous strain in the direction where a fracture is desired.

Cutting.—Cutting instruments act, in dividing bodies, upon the same principle as the wedge. The blade of the instrument is in general a thin wedge, but the edge itself is usually much more obtuse. Mr. Nicholson has estimated the angle which is formed ultimately by the finest cutting edge, at about fifty-six degrees. If the edge of an instrument were not angular, but rounded or square, it would still act as a wedge, by pushing before it a wedge-shaped portion of the opposing particles, as is done by obtuse bodies moving in fluids. In general, an oblique motion is more favorable to cutting, than a direct, and this is because the edges of steel instruments are rough with minute asperities, like saw-teeth. This circumstance, however, is of less importance when the material operated upon is very firm and the cutting is deep; for in this case, the friction and compression consume more force, than the actual division. This takes place with axes and chisels, which are necessarily made thick, to secure the requisite strength.

The quality in tools which is called *temper*, is opposed to brittleness on the one hand, and to flexibility on the other. Independently of the quality of the metal, it appears to be somewhat influenced by temperature, since axes and other tools are liable to break, or gap, in frosty weather, and razors cut best after being immersed in hot water.

The kind of cutting which is performed by scissors, depends upon the process called *detrusion*, in which the coherent particles are pushed by each other in opposite directions. In this case, the cutting edges require to be angular, but the angle not very acute. The shearing of woollen cloths, the slitting and punching of metals, the

cutting of nails, and various other mechanical processes, are performed on this principle.

Cutting Machines.—A variety of fibrous and woody substances, used by druggists and dyers, require to be reduced to a coarse powder like saw-dust, to facilitate the extraction of their soluble matter. This is not easily done in any of the common mills, owing to the toughness of the material. It is sometimes effected by machinery with circular rasps or saws, but a more economical application of a dividing force in these cases, is obtained by the rapid revolutions of a sharp cutting instrument. In a machine for cutting straw, a number of blades revolve upon an axis, with a fly. In Blanchard's ingenious engine for cutting definite forms by a pattern, sharp instruments, of different forms, are made to revolve upon axles, or slide in groves, while the material operated on is put in motion, so as to place itself in the proper position to receive the cut.

Planing machines have been variously constructed, in which the board, or substance to be planed, passes under an edge which cuts away the surface to an even depth. This edge is sometimes stationary, but more frequently a succession of cutting tools revolve with great rapidity, cutting away small successive portions of the surface. The form and direction of the shavings thus removed, is various, according to the direction of the axis about which the cutter revolves. Machines for cutting *shingles* and *laths*, are contrived on a variety of principles. One of the most effectual of these consists of a large, upright, revolving iron disc, the anterior surface of which is smooth, and furnished with two knives, or cutters, of different obliquity. A block of wood, previously made soft by steaming, is pressed against the surface of the revolving iron, so that each knife in turn strikes off a wedge-shaped slice, or shingle, of the size of the block.

Penetration.—Bodies are penetrated either by pushing aside a portion of their substance, as in driving a nail; or by removing a portion, as in boring and drilling. In addition to the force of cohesion, the resistance opposed by a solid, or even by a soft substance, to the motion of

a body tending to penetrate it, appears to resemble, in some measure, the force of friction, which is nearly uniform, whether the motion be slow or rapid, destroying a certain quantity of momentum in a certain time, whatever the whole velocity may be, or whatever may be the space described. Hence arises an advantage in giving a great velocity to a body which is to penetrate another, since the distance to which a body penetrates will be nearly as the square of its velocity.* The same remark applies equally to the action of cutting instruments. The effect of a hammer in driving a nail, depends partly on the influence of velocity in modifying friction, and partly upon the momentum accumulated in the hammer, the effect of which resembles that of a fly wheel.

Boring and Drilling.—The processes of boring and drilling, performed by gimlets, augers, centrebits, drills, &c., is a species of circular cutting, in which a cylindrical portion of the substance is gradually removed. Drills are made to turn rapidly, either in one direction by means of a lathe wheel and pulley, or alternately in opposite directions, by a spiral cord which coils and uncoils itself successively upon the drill, and is aided by a weight or fly. In boring cannon, the tool is at rest, while the cannon revolves, and by this arrangement the bore of the cannon is formed with more accuracy than according to the old method of putting the borer in motion, perhaps because the inertia of so large a mass of matter assists in defining the axis of the revolution with more accuracy. The borer is kept pressed against the cannon by a regular force. Cylinders of steam-engines are cast hollow, and afterwards bored; but in this case the borer revolves, and the cylinder remains at rest. In either case, it is important that the axis of the borer, and that of the cylindrical material, should coincide; for when it is otherwise, if the borer revolves, it will perforate obliquely, and if the material revolves, the perforation will be conical.

Mortising. Square holes, or those having a rectangular outline, are usually cut by mortising with a chisel and

* See Young's Natural Philosophy, vol. i. p. 225, and Playfair's, vol. i. p. 97.

mallet. The operation is commonly performed by hand, but it is also executed by various machines, consisting of ingenious combinations of chisels, borers, punches, and saws.

Turning.—Turning is an elegant operation, used to produce regular figures the section of which is circular. Like boring, it is a species of circular cutting, and is performed in a well-known machine called a *lathe*, in which the material to be cut revolves about its axis, while the tool is kept stationary and supported by a rest. Besides circular forms, it may also be used to produce regular curvilinear figures, which may be multiplied indefinitely. The effect of most lathes of complicated construction, depends on a certain degree of motion, of which the axis is capable. If this motion be governed by a frame producing an elliptic curve, any number of ovals having the same centre may be described at once; and if a movable point connected with the work, be pressed by a strong spring against a pattern of any kind, placed at one end of the axis, a copy of the same form may be made at the other end of the axis. Geometrical lathes, governed by eccentric wheels, and capable of describing an indefinite variety of complex figures, upon a metallic plate, are used for bank notes and ornamental designs.

Attrition.—The action of files, rasps, grindstones, and hones, consists in successively cutting or breaking away minute particles from the surface of bodies. They are used chiefly for wearing off portions of hard substances, particularly metals. The surface of grindstones and whetstones, is kept moist with water or oil, the use of which is not so much to obviate the production of heat by friction, as to prevent the adhesion of foreign particles from filling up the insterstices of the grit. In the finer kinds of grinding and polishing, certain hard substances are used in the form of powder, such as emery, tripoli, sand, putty, oxide of iron, &c.

Sawing.—*Saw Mill.*—A saw, in many respects, resembles a rasp, and acts by cutting or breaking away large particles in the direction of its own plane. The thinner the saw is, the easier is the operation, since a

smaller amount of substance is removed by the teeth. For the sake of this advantage, and for economy of the material, the blades of saws are made thin, and often stretched upon frames, to compensate the want of rigidity. Saw mills erected for cutting logs into boards, consist usually of saws attached to frames, which have a reciprocating motion communicated to them by a crank connected with a water-wheel or steam-engine. A ratchet wheel is connected with the saw by means of a bar and click; so that at every stroke of the saw, the wheel is turned the length of one tooth. The ratchet wheel acts by means of a rack, upon a carriage, which supports the log, causing it slowly to advance, until the whole length of the log has passed the saw.

Circular Saw.—Circular saws, revolving upon an axis, have the advantage that they act continually in the same direction, and no force is lost by a backward stroke. They also are susceptible of much greater velocity than the reciprocating saws, an advantage which enables them to cut more smoothly. The size of circular saws, however, is limited; for, if made too large, and of the usual thinness, they are liable to waver, and bend out of their proper plane; and, on the other hand, if made thick enough to secure an adequate degree of strength, they waste both the power and the material, by cutting away too much. Hence, they are not commonly applied to the slitting of large timber, but are nevertheless very useful in smaller works, for cutting off bodies which can be included within a certain distance of the axis, and thus allow the saw to be of small size. Circular saws, however, of large size, are used in cutting thin layers of mahogany for *veneering*; for in this case the saw can be strengthened by thickening it on one side towards the centre, the flexibility of the layer of wood allowing it to turn aside, as fast as it is sawn off. Circular saws may be rendered more steady by giving them a greater velocity, so that the centrifugal force shall assist in confining the saw to its proper plane.

An ingenious machine has been invented in Maine, for sawing off sheets of wood of an indefinite length, for

veneering, by cutting a spiral layer from the surface of a cylindrical log, the layer being turned off like a riband, when unwound from a roller. The sheets of *rice paper*, mentioned on page 196, *note*, are said to be cut in the same spiral manner.

Dovetailing machines are made with circular saws, constructed to cut obliquely, and entering in different directions. Or, instead of saws, small wheels are used, with cutters on their circumference. *Tenons*, or the parts intended to enter mortises, also *tongues*, *rabbets*, &c., are cut on similar principles.

The sawing of marble is performed by saws made of soft iron, and without teeth. A quantity of sand and water is kept interposed between them, and the sand, becoming partly imbedded in the iron, serves to grind away the marble. These saws are worked horizontally, for the convenience of retaining the sand, and are moved either by hand, or by reciprocating machinery. The cylindrical blocks, which form the tambours, or frusta, of columns, are sometimes cut out of marble, by perforating the block at the centre, and inserting an iron axis, to the ends of which are attached frames, upon which a narrow, or a concave, saw is stretched parallel to the axis. An alternating motion is then given to the frame, until the saw has cut its way round the axis.

Crushing.—When materials require to be broken into minute parts, or when the texture of vascular substances is to be destroyed, that they may yield their fluid contents, the operation of crushing is resorted to. It is performed either by percussion, with hammers, stampers, and pestles, or by simple pressure, with weights, rollers, and runner stones.

Stamping Mill.—For reducing the ores of metals to powder, a number of heavy vertical bars, called stampers, are alternately raised, and suffered to fall, by the action of cams or wipers, projecting from the arbor of the mill-wheel. The ore is placed in a trough or mortar beneath, where it is acted upon by the stampers, until it is sufficiently comminuted. A stream of water continually runs through the stamping trough, carrying with it the particles,

which have become fine enough to pass through a screen provided for the purpose.

Bark Mill.—The bark used by tanners is reduced to a coarse powder in various ways. One of the most common methods, is, to crush the bark by the revolutions of a circular stone, called a ***runner stone***, which resembles the wheel of a carriage, travelling round in a continued circuit. The axis of the stone is connected with a vertical shaft, so that the stone has two motions, one round its own axis, which is horizontal, and the other round the vertical shaft. The bark is raked up into a ridge before the stone, and is crushed or ground up, by the edge of the stone rolling over it. In some more complicated mills, the bark is successively cut with knives, beaten with hammers, and ground with stones, or cylinders.

Oil Mill.—The oleaginous seeds from which oil is expressed, require to have their substance previously broken up by the operations of a mill. In one of the best forms of the oil mill, the seeds are first bruised to the consistence of paste, by the action of runner stones. The paste is received in troughs perforated with holes, through which a portion of the oil drips, and this part is considered the most pure. The paste is then put into strong bags, and subjected to pressure as long as it yields oil. The remaining paste, or ***oil cake***, is next taken out of the bags, broken to pieces, and put into mortars. It is here beaten by the action of heavy stampers, until reduced to a very minute state of subdivision. The oil which is next pressed out from it is inferior in quality to the first, in consequence of its containing more mucilage and farinaceous particles. The seeds are nevertheless subjected to another pressure, after having been exposed to heat, which enables them to yield a quantity more of oil, but of a still poorer quality.

Sugar Mill.—The machine by which sugar canes are crushed, usually consists of three vertical rollers, the middle one of which is turned by a horse, or other power, and turns the remaining two by friction, or by toothed wheels; the latter method being most advantageous. The canes are supplied by attendants, and are drawn in and crushed between the first and second rollers, after

which they return and pass between the second and third. The juice, which is pressed out by the same operation, flows into a trough beneath.

Cider Mill.—When the substances to be crushed are so large that they cannot readily be drawn in between smooth cylinders, it is necessary that the rollers should be indented at their circumference. The common cider mill is formed with two indented cylinders, the teeth of one of which enter the indentations of the other. By this arrangement, the fruit to be ground is caught by the projecting parts of the rollers, and regularly carried forward and crushed. Formerly it was the custom to grind apples by runner stones, similar to those used in bark mills. And at the present day cylindrical rasps are sometimes employed, being supposed capable of destroying the texture of the fruit more effectually.

Grinding.—Grinding, in its most limited sense, may be considered as a species of crushing, or breaking, in which the force acts partly in a lateral direction, so as to lacerate, rather than compress, the material acted upon. It is frequently produced, in small mills, by a cylinder or cone, turning within another, which is hollow, the surfaces of both being cut obliquely into teeth. In larger mills, it is commonly performed by one stone moving upon another.

Grist Mill.—The common mill for grinding grain, is constructed with two circular stones placed horizontally. Buhrstone is the best material of which millstones are made, but sienite and granite are frequently used, for Indian corn and rye. The lower stone is fixed, while the upper one revolves with considerable velocity, and is supported by an axis passing through the lower stone, the distance between the two being capable of adjustment, according to the fineness which it is intended to produce in the meal, or flour. When the diameter is five feet, the stone may make about ninety revolutions in a minute, without the flour becoming too much heated. The corn or grain is shaken out of a hopper by means of projections from the revolving axis, which give to its lower part, or feeder, a vibrating motion. The lower stone is slightly convex, and the upper one somewhat more concave, so that

the corn, which enters at the middle of the stone, passes outward for a short distance, before it begins to be ground. After being reduced to powder, it is discharged at the circumference, its escape being favored by the centrifugal force, and by the convexity of the lower stone. The surface of the stones is cut into grooves, in order to make them act more readily and effectually on the corn; and these grooves are cut obliquely, that they may assist the escape of the meal, by throwing it outward. The operation of *bolting*, by which the flour is separated from the bran, or coarser particles, is performed by a cylindrical sieve placed in an inclined position, and turned by machinery. The fineness of flour is said to be greatest when the bran has not been too much subdivided, so that it may be more readily separated by bolting. This takes place when the grinding has been performed more by the action of the particles upon each other, than by the grit of the stone. For this sort of grinding, the buhrstone is peculiarly suited.

Color Mill.—The various coloring substances used by painters, when they are not soluble in oil or water, require to be reduced to an impalpable powder by grinding. This is commonly performed upon a smooth stone slab, by trituration with another stone, called a *muller*. When the grinding is performed by machinery, a large muller of the shape of a pear, having a groove cut in it for the admission of the paint, is made to revolve in a mortar, the bottom of which is of a corresponding shape. In some color mills, a horizontal stone cylinder revolves in contact with another stone, which is concave, and covers a part of its convex surface. In most cases, the substance to be ground is mixed with oil or water. As some of the substances used for pigments are of a poisonous character, they should be ground in close cavities, or under water.

MODES OF UNION.

Insertion.—The mechanical modes of attaching bodies to each other, usually consist in the insertion of their parts among each other, or in the application of other substances specially adapted for the purpose of connection. In-

sertion is performed by various modes, the principal of which are, 1. *Mortising*, in which the projecting extremity of one timber is received into a perforation in another. 2. *Scarfing* and *interlocking*, in which the ends of pieces overlay each other, and are indented together, so as to resist longitudinal strain by extension, as in tie beams, and ends of hoops. 3. *Tongueing* and *rabbeting*, in which the edges of boards are wholly, or partly, received by channels in each other. 4. *Dovetailing*, when the parts are connected by wedge-shaped indentations, which permit them to be separated only in one direction. 5. *Linking*, where the ends of flexible rods are bent over each other. 6. *Folding*, when the edges of flexible plates are connected in a similar manner. 7. To these may be added the combinations of flexible fibres, by tying, twisting, weaving, &c., in which the permanency of the union depends upon friction.

Interposition.—When two substances are mechanically united by the intervention of a third, the latter, from its smaller size, should be made of the strongest material. *Nails* are a common connecting medium in wooden structures. The stability of a nail depends upon its friction, or adhesion, and is increased by its roughness, the smallness of the angle made by its sides, and the elasticity of the material into which it is driven.

When the force tending to produce separation is great, nails do not afford an adequate security. In such cases, it is common to employ *screws*, which are inserted by the force of torsion, and cannot be withdrawn by that of extension, while the material is sound. Where great strength is required, *bolts* of metal are used, which pass through the substances to be connected, and are secured at their smaller extremity by a nut and screw, or by a transverse key. *Rivets* are short bolts, the two ends of which are headed, or spread by hammering, after they are inserted.

Binding.—In some cases, the materials to be connected are not perforated, but surrounded by the connecting substance. Hoops and bands of metal, wood, and flexible fibres, are used for this purpose. In cases where it is applicable, binding ordinarily affords the strongest mode

of connection, but is attended with the greatest expenditure of the connecting material.

Locking.—For the temporary connection of parts, which requires to be often repeated, latches, bolts, hooks, buttons, and locks are employed. Of these, the *lock* is the only one whose structure is at all complicated. The principle upon which locks depend, is the application of a lever to an interior bolt, by means of a communication from without. The lever is the key, and the bolt receives from it a progressive motion in either direction. The security of a lock depends upon the number of obstacles which can be interposed between the movement of the bolt, and the action of any instrument except the proper key. The *wards* of locks are impediments of this kind, and to enable the key to pass them, certain portions of its substance are cut away. Various complicated and difficult locks have been constructed by Messrs. Bramah, Taylor, Spears, and others. In a very ingenious lock invented by Mr. Perkins, twenty-six small blocks of metal, of different sizes, are introduced, corresponding to the letters of the alphabet. Out of these, an indefinite number of combinations may be made. The person locking the door, selects and places the blocks necessary to spell a particular word known only to himself, and no other person, even if in possession of the key, can open the door without a knowledge of the same word.

Cementing.—Cements are, for the most part, soft or semifluid substances, which have the property of becoming hard in time, and cohering with other bodies to which they have been applied. A variety of these substances are used for uniting different materials. The compounds of lime and sand, which constitute the ordinary building cements, have been considered in Chapter II. For uniting pieces of marble, plaster of Paris, dried by heat, and mixed with water, or with rosin and wax, is employed. A cement for iron is made by mixing sulphur and muriate of ammonia with a large quantity of iron chippings. This is used for the joints of iron pipes, and the flanges of steam-engines. Turners, and some other mechanics, confine the material on which they are working,

by a cement composed of brick-dust and rosin, or pitch. The cement used by glaziers, under the name of *putty*, is a mixture of linseed oil and powered chalk. China ware is cemented by common paint, made of white lead and oil, or by resinous substances, such as mastic and shell lac, or by isinglass dissolved in proof spirit or water. Bookbinders, and paper hangers, employ *paste*, made by boiling flour; and a similar, but more elegant article, under the name of *rice glue*, is prepared by boiling ground rice in soft water to the consistence of a thin gelly. *Wafers* are made of flour, isinglass, yeast, and white of eggs, dried in thin strata upon tin plates, and cut by a circular instrument. The color is given by red lead, and other pigments. *Sealing wax* is composed of shell lac and rosin, and is commonly colored with vermilion.

Glueing.—For uniting wood and similar porous substances, common glue takes precedence of all other cements. It is dissolved by heating it with water, and is applied with a brush to both the surfaces to be united. Glue does not adhere so readily, if the surfaces be in the least oily, or if a coating of old glue is previously upon them, or, indeed, if the pores are filled with any foreign substance. The cementing power of glue depends upon the strength which it possesses when dry, and the hold which it obtains upon the wood, by penetrating its pores. It does not furnish a sufficient bond of union for surfaces which are not porous, as those of metals; and it is not durable when exposed to the action of water.

Welding.—Certain metals, such as iron and platinum, which are exceedingly difficult of fusion, are capable of being united by the process of welding. This consists in hammering them together while they are at a very high temperature. Bar iron cannot be welded without raising it to a heat of nearly sixty degrees of Wedgewood's pyrometer. Cast steel would be melted at this temperature, and therefore in welding iron to steel, the steel is raised only to a common white heat. Care is taken to prevent the surfaces which are to be welded from being oxidized too much, or else to detach the scales when the metal is brought to a welding heat. The union of welded pieces

probably depends on an incipient fusion of their surfaces. When properly conducted, the metal is supposed to be as strong in the welded part as in any other.

Soldering.—The process of soldering consists in uniting together parts of the same, or of different metals, by the intervention of a metallic substance employed in a state of fusion. It is necessary that the uniting substance should melt sooner than the substance to be soldered, that it should adhere firmly to its surface, and, as far as practicable, approach to the metal soldered, in hardness and color. Iron is usually soldered with brass, and hence the process is commonly called *brazing*. An alloy of tin and iron is sometimes used instead of brass, for the same purpose. Copper may be united either by a hard solder made of brass and zinc, or a soft solder composed of zinc and lead. Tin is soldered with pewter made of tin and lead, with sometimes a portion of bismuth. Gold and silver are united with solders made of gold or silver, alloyed with copper or brass. Platinum is soldered with gold. The adhesion of solders depends upon an alloy being formed between the surfaces in contact.

As the oxidation of the surface of metals tends to prevent the adhesion of the solder, it is common to unite with the solder some additional substance, which may obviate this difficulty. In soldering copper, brass, iron, &c., it is common to employ borax, a salt which fuses at the time when the metals would be most liable to oxidate, and, by enveloping the metallic surface, prevents the further action of the oxygen of the atmosphere. Potash, soda, tartar, and various salts are used for the same purpose. Muriate of ammonia has a remarkable effect in freeing the surfaces of metals from oxygen, which it does, apparently, by combining with the metallic oxide, and carrying it off as it sublimes. In soldering the more fusible metals, as tin and lead, a carbonaceous substance is employed, such as rosin, or oil, which tends to cover the surface, and also to reduce the oxide to its metallic state, as fast as it is formed.

Casting.—The process of fusion, or melting, affords, in many substances, the most effectual method both of

destroying the cohesion of their particles, and of afterwards restoring it under new arrangements. Many substances, both simple and compound, such as metals, glass, wax, &c., may become liquid and again solid, without essentially changing their physical qualities. On the other hand, many natural bodies, crystallized minerals, and organic combinations, cannot be fused without changing their characteristic properties. Some substances are with difficulty fusible when alone, but become more fusible when combined with another substance, as is the case of sand with an alkali, or iron with carbon. Others again have their fusibility lessened by combination, as happens in metals when they become oxidized.

Fluxes.—The name of *fluxes* has been given to certain substances which assist fusion, either by expediting the process, or by protecting the substance melted from alteration. In separating metals from their ores, fluxes are employed, to render the substances with which the metal is combined, capable of fusion. Thus if the ore abound with silicious earth or stone, an alkaline flux, such as potash, soda, or tartar, has the effect of combining with the silicious substances, and forming with them a vitreous compound, which floats upon the top of the melted metal. Tartar also contains a portion of vegetable matter, the carbon and hydrogen of which serve to deoxidize the metal. Borax, common salt, and many other saline bodies, when melted, prevent the oxidation of metals, by protecting their surface from the atmosphere. Muriate of ammonia, rosin, fatty substances, powdered charcoal, &c., prevent or remove oxidation, by combining either with the oxygen, or with the oxide when formed.

Moulds.—The moulds used for casting melted bodies must be suited to the temperature at which the body melts. For metals which melt at a high heat, as copper, brass, cast iron, &c., the moulds are made of some refractory substance, such as loam, sand, pounded brick with plaster, or clay, &c. Glass is cast in moulds made of copper, but these require to be frequently cooled. Those bodies which melt at temperatures below that of ignition, as tin, lead, wax, &c., may be cast in moulds

of any convenient metal, or of wood, and other inflammable materials.

The forms of some bodies may be changed, and their separation or union effected, without the agency of fusion, in various ways. It may be done by mixture with water, as in clay and plaster; by solution in water, as in glue, rice, and gum; and by sublimation, as in camphor, and muriate of ammonia.

WORKS OF REFERENCE.—YOUNG'S Lectures on Natural Philosophy;—GREGORY'S Mechanics;—NICHOLSON'S Operative Mechanic, 8vo.;—GRAY'S Operative Chemist, 8vo. 1828;—REES'S Cyclopedia, and BREWSTER'S Edinburgh Encyclopedia, under various heads.

CHAPTER VI.

OF CHANGING THE COLOR OF MATERIALS.

OF APPLYING SUPERFICIAL COLOR.—Painting, Colors, Preparation, Application, Crayons, Water Colors, Distemper, Paper Hangings, Flock Paper, Fresco, Encaustic Painting, Oil Painting, Varnishing, Japanning, Polishing, Lackering, Gilding, Photography. OF CHANGING INTRINSIC COLOR.—Bleaching, Dyeing, Mordants, Dyes, Calico Printing.

AN extensive branch of industry has for its object the effecting of changes in the natural colors of bodies. The artificial modifications, produced in color, may be either mechanical and superficial, or chemical and intrinsic. In painting, gilding, and similar processes, the original color of a substance is not altered, but it is mechanically concealed by another substance which covers it from view. On the other hand, in bleaching and dyeing, the color of the whole substance is intrinsically changed, by a chemical action. This difference of character has given rise to distinct arts in coloring, the processes of which are for the most part dissimilar.

OF APPLYING SUPERFICIAL COLOR.

Painting.—Common painting, when disconnected with

design, has for its object to produce a uniform and permanent coating upon surfaces, by applying to them a compound, which is more or less opaque. In many cases painting is applied only for ornament, but it is more frequently employed to protect perishable substances from the changes to which they are liable when exposed to the atmosphere, and other decomposing agents. The effect and durability of different coverings employed in this way, depends upon the kind of pigment used, and still more upon the vehicle, or uniting medium, by the intervention of which it is applied.

Colors.—The coloring substances, employed by painters, comprise a great variety of articles derived from the mineral, vegetable, and animal kingdoms. They are employed in a state of minute subdivision, and commonly mixed with a fluid which is more or less viscid and tenacious. When applied upon the surface of canvass, wood, or other bodies, they communicate their color, by covering and concealing the original color of the surface, while they substitute their own instead. Those which are perfectly opaque, are called *body colors*, such as white lead, and vermilion ; while those which are partially pellucid, are called *transparent colors*, as prussian blue, terra di sienna, and lake. Transparent colors do not wholly conceal the colors beneath them, but produce the combined effect of the two. The process called by painters *glazing*, consists in laying a transparent color over one of a different tint. Transparent colors are sometimes mixed with a white earth, to give them a body, where it is necessary to cover entirely the previous surface. Common whiting is usually employed for this purpose.

The following list comprises the principal coloring substances, used as paints, exclusive of those which belong only to the art of dyeing.

Blues.—*Ultramarine* is the richest and most durable of all the blues. It is not altered by time, and bears exposure to a red heat without changing its color. It is made only from the *lapis lazuli*, a stone brought from several parts of Asia, which bears an extremely high price.

Prussian blue is a strong and durable color. In the present language of chemistry, it is a ferrocyanate of the peroxide of iron. It is made from blood, and other animal matters, dried, and heated to redness with an equal weight of pearlash. The residue, which consists chiefly of cyanuret of potassium, and carbonate of potass, is dissolved in water, and after being filtered, is mixed with a solution of alum and protosulphate of iron. A greenish precipitate ensues, which, by exposure to the atmosphere, passes through different shades, till it arrives at a fine blue color.

Blue verditer is a nitrate of copper combined with hydrate of lime. It is made by adding quicklime to a solution of copper in nitric acid, and mixing the precipitate with a small portion more of lime. It is a full blue, much used in paper staining, but is liable to grow dull.

Smalt is a powdered glass, which derives its blue color from the oxide of cobalt. It is chiefly used by strewing it on a ground of some other color.

Bice consists of smalt finely levigated. It is rather lighter, and very durable, but not extensively used.

Indigo is the deepest of all the blues in common use. It is very durable, but more used in dyeing (which see) than in painting. *Stone blue*, *Fig blue*, *Queen's blue*, &c., consist of indigo reduced by starch.

Reds.—*Vermilion* is a bisulphuret of mercury, formed by fusing sulphur with about six times its weight of mercury, and subliming in close vessels. The product is called *Cinnabar*, and, when powdered, vermilion. It is of a bright scarlet color, and stands tolerably well.

Red lead, otherwise called minium, is a deutoxide of lead, formed by exposing lead, or litharge, to heat in a furnace, in open vessels, with a current of air passing over it. The metal is gradually converted into an oxide of a bright orange red. Red lead is extensively consumed in the manufacture of flint glass. As a pigment, it is brilliant at first, but liable in time to turn black.

Chrome red is a fine scarlet, formed by boiling carbonate of lead with an excess of chromate of potass. By Dulong's method, sixty-seven parts of white lead are boiled with eighty-two parts of chrome yellow, in water.

Colcothar, also called *crocus martis*, and *rouge d'angleterre*, is an impure brown-red oxide of iron which remains after the distillation of the acid from sulphate of iron. It forms a durable color, but is most used by artists in polishing glass and metals.

Ochres.—The ochres are various earths containing iron in a greater or less degree of oxidation. *Venetian red* is a coarse ochre of a dark red color. *Indian red* is an ochre brought from the East Indies, and has a shade inclining to purple. *Red ochre* is formed from yellow ochre by exposing it to heat. *Burnt sienna* is made from the raw terra di sienna by exposure to heat, by which process its color is changed from yellow to red. *Bole* is a fine clay, colored by oxide of iron, of which there are many varieties, from yellowish red to brown.

Carmine, the most beautiful of all the reds, is an animal substance made from the cochineal insect, or *Coccus cacti*. It is deposited from a decoction of powdered cochineal in water, to which alum, carbonate of soda, or oxide of tin is added ; but the preparation of the finest varieties is kept secret by the manufacturers, and probably depends much upon the delicacy of the manipulations. A fine color is said to be made by adding acetic acid to a solution of carmine in ammonia.

Lakes of various shades are formed from cochineal precipitated by salts of tin, and other agents. Beautiful lakes are also prepared from madder, by a process of Sir H. Englefield, in which the coloring substance is precipitated from an infusion of madder, by adding solutions of alum, and carbonate of potass. The lake called *rose pink*, is an extract of Brazil wood, mixed with whiting and alum.

Rouge is made from the flowers of the *Carthamus tinctorius*, or Dyer's saffron, (also called safflower,) by dissolving an alkali in the infusion, and precipitating the coloring matter by lemon juice. It is very fugacious. Under the same name other pigments are also used.

Yellows.—*Gamboge* is the concrete juice of a tree growing in the East Indies, (*Stalagmitis cambogioides.*) It is externally of a dull orange color, but becomes of a

bright yellow, when wet, or thinly spread upon a white surface. It is partially soluble in water and alcohol, and is chiefly used in water colors.

Orpiment is a sulphuret (sesquisulphuret) of arsenic. The paint called *king's yellow*, is made from this substance, or from its constituents. It is a brilliant, but not very durable color, and its use is in some cases dangerous to the health.

Naples yellow is prepared by exposing lead and antimony with potass, to the heat of a reverberatory furnace. It stands tolerably well, but turns black upon the contact of iron. A native pigment of this kind is also obtained from a species of lava.

Yellow ochre is a native earth, the finer particles of which, are separated by washing, as in similar substances. Although not very bright, its cheapness and durability have caused it to be extensively used.

Terra di sienna is also an ochre, of a deeper and brighter yellow than most of the others.

Massicot or *masticot*, is the protoxide of lead, prepared by collecting the gray film which floats upon the surface of melted lead, and exposing it to heat and air until it assumes a yellow color.

Chrome yellow is a chromate of lead. It is precipitated by adding chromate of potass in solution, to a solution of nitrate, or acetate, of lead. It forms one of the most brilliant yellows, and is extensively manufactured in this country, from the chromate of iron found near Baltimore.

Turpeth mineral is a subsulphate of mercury, or rather a sub-bisulphate. It is a pale yellow, and moderately durable.

Patent mineral yellow is a fused muriate of lead, made by decomposing common salt by means of litharge, triturating the product with water, washing away the soda, and drying and fusing the muriate.

Dutch pink is a cheap color used by paper stainers, composed of whiting colored by a decoction of dyers' wood, quercitron, or French berries, with alum.

Greens.—*Verdigris* is an acetate of copper, or, strict-

ly, an impure acetate of the peroxide of copper. It is manufactured in the south of France, by covering plates of copper with the refuse of the grapes, after making wine. It may also be formed by exposing copper to the vapor of vinegar.

Terra verte is a native blue-green ochre. It is semitransparent and durable, but not very bright.

Brunswick green, called also *mineral green*, is an ammoniaco-muriate of copper, much used for paper hangings, and occasionally in oil painting.

Sap green is the inspissated juice of the berries of the buckthorn, (*Rhamnus catharticus.*) It is semitransparent, and chiefly used in water colors.

Many of the greens in common use are compound colors, made by the admixture of blue with yellow.

BROWNS.—*Umber* is a light brown ochre. Burnt umber is the same substance, having its color darkened by exposure to heat. It is durable in both states.

Spanish brown is a coarse durable ochre, its color inclining to red.

Bistre is prepared from common soot of wood, by pulverizing and washing. The soot of the beech is said to afford the best.

Asphaltum is prepared from the bituminious substance of that name. When dissolved in oil of turpentine, it is semitransparent, and is used as a glaze.

Ox gall consists of the biliary concretions found in the gall-bladder of cattle. It is not soluble in water or alcohol, but dissolves readily in a solution of potass. It is of a yellowish brown, and is much valued for the brightness and permanence of its tint. The liquid ox gall is used by painters to facilitate the laying on of colors.

BLACKS.—*Lamp black* is a light carbonaceous substance, thrown off during the combustion of resinous and oily substances. The chips of fir and pine trees are burnt under tents, to the inside of which the lamp black adheres.

Frankfort black.—This is a charcoal made from the lees of wine. It is used in the ink of copperplate printers.

Ivory black, called also *Cologne black*, is made from the shavings and dust of ivory, heated in covered iron pots. Various other carbonaceous colors are made from cork, vine twigs, peach stones, &c., converted into charcoal.

Indian ink is said to be made from different sorts of lamp black, mixed with water and glue. The black is obtained from the smoke of oil, of fir wood, or of horse chestnuts. A solution of lac with borax in water, is said to be the vehicle of the lamp black in some kinds.

Sepia is the black liquid obtained from the cuttle fish. It is of a viscid consistence, and is preserved by drying it upon saucers or shells.

WHITES.—*White lead*, formerly *ceruse*, is a carbonate of lead, prepared by exposing coils of sheet lead, in earthen pots, to the vapor of vinegar for several weeks. It is sometimes also formed by precipitation with carbonic acid from a solution of acetate of lead in water.

Flake white consists of the densest and thickest scales, which are separated in making the foregoing article from sheet lead. It is very pure, whereas the white lead of commerce is adulterated with chalk.

Pearl white is the subnitrate of bismuth, formerly called magistery of bismuth, precipitated by water from its solution in nitric acid. It has been used as a cosmetic, but grows yellow by age and light.

Whiting.—Common chalk, separated, in the form of an impalpable powder, by washing. *Blanc de Troyes* is similar to whiting.

Zinc white is the oxide of zinc. It does not work easily, but is thought very durable. Various marls and clays from *Bougival*, *Rouen*, *Moudon*, &c., are used for white pigments.

Preparation.—Coloring substances, before being used in painting, require to be reduced to a state of extreme fineness. For this purpose, they are ground in a color-mill, and levigated with a stone and muller. In many cases, colors, which are insoluble in water, are separated by washing, the water being first made turbid with the coloring substance, and left to stand a short time, till the

coarser particles have subsided. The upper part of the fluid, with the finer particles in suspension, is then poured off, and the second deposit which takes place from this is sufficiently fine for mixing. When a greater degree of tenuity is required, the washing is repeated.

Application.—As colors are first prepared for use by simply reducing them to powder, it is necessary that some tenacious fluid should be introduced to make their particles adhere to the surface on which they are spread. To effect this end, various fluids are employed, and the difference of the material used, with the method of employing it, has given rise to the modes of painting in water, in oil, in fresco, in distemper, &c.

Crayons.—The most simple mode of applying colors is by the use of crayons. Crayons are cylinders, or sticks, of dry colors, cemented into a friable mass like chalk, by the assistance of gum or size, and sometimes of clay. They are used by simply rubbing them upon paper, and afterwards blending and softening the shade by means of a *stump*, or small roll of leather, or paper. But drawings in crayons and chalks, have always the disadvantage, that they do not adhere to the paper, but are rubbed off, and defaced, with the slightest attrition. In this state, they can be safely kept and examined only in frames under glass. Various modes have been practised for fixing crayon drawings upon paper, so as not to be liable to defacement. Among other means, this end may be effected by brushing the back of the paper with a strong solution of isinglass, or by passing the drawing through a powerful press, in contact with a moist paper.

Water Colors.—The most common mode of painting on paper, is by the use of water colors. These are formed into hard cakes or lozenges, with a larger quantity of gum than is employed for crayons. When used, they are rubbed down with water upon glass, or a glazed surface, and applied while wet with a camels' hair pencil. The gum with which they are mixed, causes them to adhere so closely to the paper that they cannot be rubbed off.

Distemper.—Painting in *distemper* is used for works

to-be executed upon a larger scale, such as stage scenery, the walls of apartments, &c. The colors are used in the form of powder, and are mixed with water rendered glutinous by size, or other solutions of animal glue. The mixture requires, in many cases, to be used warm, as the solution becomes stiff upon cooling. Skimmed milk also serves as a vehicle for painting in distemper, and its tenacity is increased by adding small portions of lime, and of linseed or poppy oil. The mixture dries speedily, the oil being converted into a soap by the lime.* Distemper in *badigeon* is employed by the French to restore the original color to stone walls which have become brown by time; and consists in washing them with powder of the same kind of stone, properly mixed. *Chipolin* is a varnished distemper.

Paper staining.—Paper hangings, for the walls of rooms, were originally introduced in China, and some of the more elaborate kinds are printed by hand. But the method, now almost universally employed, consists in printing by blocks. The ground color is first laid upon the paper with a brush, after which, the figures are stamped by wooden blocks engraved for the purpose. Each color requires a separate block, and these are used in succession, the workmen being guided by a pin in placing the blocks, so as to prevent the colors from interfering. The glazing of the paper is performed by a smooth brass roller.

Flock paper, commonly called *cloth* paper, is made by printing the figures with an adhesive liquid, commonly linseed oil boiled or litharge. The surface is then covered with the flocks, or woollen dust, which is produced in manufactories by the shearing of woollen cloths, and which is dyed of the requisite colors. After being agitated in contact with the paper, the flocks are shaken off, leaving a coating, resembling cloth, upon the adhesive surface of the figures.

* This method is highly recommended by Tingry, who gives the following recipe. Skimmed milk, four pounds; lime, newly slaked, six ounces; linseed, nut, or poppy oil, four ounces; Spanish white, (white clay,) three pounds.

Fresco.—Paintings in *fresco* are executed upon walls recently plastered, before they have become dry. The coloring substance, mixed with water, being applied while the wall is wet, sinks in and incorporates itself with the grain of the mortar, so as to become very durable. When a wall is to be done in fresco, it is covered with a coating of stucco or fine mortar, which is applied in successive portions, no more being put on at once than can be painted before it is dry. This mode of finishing by piecemeal, renders it necessary that the artist should have his whole design either upon paper, or thoroughly digested in his mind, before he begins. The drawings which are executed upon large paper to serve as patterns for fresco paintings, are called *cartoons*. They are transferred to the walls by puncturing through the outlines with a sharp point.* Many of the greatest works of the most eminent Italian masters are executed in fresco, upon the walls and ceilings of the different churches and cathedrals.

Encaustic Painting.—The ancients made use of a mode denominated *encaustic painting*, the knowledge of which, at the present day is lost. From the writings of Pliny, it appears that the material with which the colors were incorporated, was wax, and that this was applied by the assistance of heat. It is represented as having been very brilliant and durable, though no specimens of it remain at this day. The principal paintings which have been discovered upon the walls at Herculaneum and Pompeii, appear to have been done in fresco.

Oil Painting.—Painting in oil, which, on many accounts, has a great superiority over other methods, was first applied to the execution of designs about the year 1410, by John Van Eyck, in Flanders. The oils, used for painting, must be of the class denominated drying oils. Of these, linseed oil is the kind most commonly employed, and its tendency to dry is increased by its being boiled. Its color renders it sometimes injurious to light tints; so that in delicate pieces it is better to employ nut oil, or poppy oil, which are nearly transparent, and do not turn

* Cartoons are also used as patterns in tapestry and mosaic.

dark in drying. The drying of paint is owing, not so much to evaporation, as to a chemical combination of the oil with the pigment, especially when the latter is a metallic oxide, or other substance, having a direct affinity for the oil. The oxygen of the atmosphere appears also to enter into this combination. The drying will be frustrated, if a small quantity of any fat oil be present. Hence, in painting old surfaces, which have been exposed to contract any greasiness, it is necessary first carefully to cleanse them, or to wash them with lime in water, or with some alkaline solution, which combines with the oil. The latter method is practised by house painters.

Oil paintings of designs are executed either on canvass, on wood, or on copper. When the colors used are chiefly of the kind denominated body colors, each successive layer conceals those beneath it, so that the work may be heightened, amended, or altered, at pleasure, during any stage of the process. Paintings in oil are very durable, and acquire a mellowness from age which improves rather than injures their effect, provided permanent colors have been used.

Painting in the large way, with uniform colors, mixed in oil, is employed, not so much for ornament, as for the protection of perishable substances from decay. Thus wood may be preserved from decomposition, and metals from oxidation, for an indefinite time, by keeping them covered with a thick coating of paint, which is impervous to air and moisture.

Varnishing.—The name of varnishes is given to certain compounds, chiefly solutions of resinous substances, which, after being spread over surfaces, and dried, possess the qualities of hardness, brilliancy, and transparency. They are employed to give lustre and smoothness to painted surfaces, and to defend them from the action of the air.

The principal substances which form the basis of varnishes, are copal, mastic, animé, sandarac, lac, benzoin, amber, and asphaltum. Of these, *copal* is a hard, shining, transparent resin, of a light citron color, originally brought from Spanish America, and erroneously considered as

the product of the *Rhus copallinum*.* True copal is soluble in oil, but is difficult of solution in alcohol. It is commonly made into varnish by dissolving it in hot linseed oil, rendered drying by quicklime, and diluting the solution with oil of turpentine. By mixture with camphor, it becomes soluble in alcohol, or in oil of turpentine. *Mastic* is a resinous substance, in the form of tears, of a pale yellow color, brittle, and semitransparent. It comes from the Levant, and is produced by the *Pistacia lentiscus*. A greater part of it is soluble in alcohol and in oil of turpentine. *Animé* is brought from Spanish America, and is said to be obtained from the *Hymenœa courbaril*. It resembles copal very much in its appearance, but is easily soluble in alcohol, while copal is not. It is often sold under the name of copal. *Sandarac* is the resin of the *Thuya articulata*, which grows in Barbary. It resembles mastic, but is rather more transparent and brittle. When chewed, it crumbles to powder, whereas mastic softens in the mouth. It is soluble in alcohol and oil. *Lac* is deposited on certain trees in the East Indies, by an insect called *Coccus lacca*. The substance in its natural state, incrusting the twigs, is called *stick lac*; when broken off, and boiled in water till it loses its red color, it is termed *seed lac*, and when melted and reduced to a thin crust, it is called *shell lac*. Stick lac has a deep red color, and yields to water a red substance which is used as a dye. Lac is soluble in alcohol. *Benzoin* is the product of the *Styrax benzoe*, a tree growing in Sumatra. It is a solid, brittle substance, in yellowish white tears, joined together by a brown substance, and is sometimes wholly brown. It is a balsam, and affords benzoic acid. *Amber* and *asphaltum* are mineral substances, already mentioned in the second chapter.

Varnishes are divided into three kinds, according to the

* The Rhus copallinum is a common shrub in the United States, and is not known to produce any substance resembling copal. According to Hernandez, the copal of Spanish America is obtained from various trees. I am informed that the copal used in this country comes almost wholly from the East Indies. It is probably the produce of the *Elæocarpus copalifera*.

menstruum in which the resinous substance is dissolved. These are *spirit* varnishes, in which the solvent is alcohol; *essential* varnishes, in which a volatile oil, commonly oil of turpentine, is used; and *oil* varnishes, which consist of a resin dissolved in a drying oil. Some vegetable juices may be applied in their liquid state. Thus the viscid juice of the *Rhus vernix* affords the celebrated black varnish used in Japan. The same shrub, which grows in this country, affords a whitish juice, which, upon boiling, yields a strong, glossy, black varnish.*

An elastic varnish may be made by dissolving caoutchouc in linseed oil and oil of turpentine; but this preparation dries slowly. Besides the solvents mentioned in the first chapter of this work, it is found that the naphtha of coal tar dissolves caoutchouc readily, and on drying leaves its properties unaltered.†

Japanning.—Japanning is the art of varnishing in colors, and is therefore a species of painting. It is most easily executed upon wood and metal, or such other substances as retain a determinate form, and are capable of sustaining the operation of drying the varnish. Paper and leather, when wrought into forms in which they remain stretched, stiff, or inflexible, are common subjects for japanning.

The article to be japanned is first brushed over with two or three coats of seed lac varnish, to form the *priming*. It is then covered with varnish previously mixed with a pigment of the tint desired. This is called the *ground color*; and if the subject is to exhibit a design, the objects are painted upon it, in colors mixed with varnish, and used in the same manner as for oil painting. The whole is then covered with additional coats of transparent varnish, and all that remains to be done, is to dry and polish it.

Japanning requires to be executed in warm apartments, and the articles are warmed before the varnish is applied to them. One coat of varnish, also, must be dry before

* See American Medical Botany, vol. i. p. 101. The shrub is poisonous to many persons.

† Annals of Philosophy, vol. xii.

another is laid on. Ovens are employed to hasten the drying of the work.

The same pigments which are employed in oil or water, answer also in varnish. For painting figures, shell lac varnish is considered best, and easiest to work; it is therefore employed in most cases where its color permits. For the lightest colors, mastic varnish is employed, unless the fineness of the work admits the use of copal dissolved in alcohol.

Polishing.—Pictures, and other subjects, to which only a thin coat or two of varnish is given, are generally left to the polish which the varnish naturally possesses, or are brightened only by rubbing them with a woollen cloth when dry. But whenever several coats of varnish or japan are laid on, a more glossy surface can be produced, by means similar to those which are used to polish metals; the surface having first been suffered to become completely dry and hard. Where the coat of varnish is very thick, the surface is first rubbed with pumice stone and oil, till it becomes uniformly smooth; the pumice having been previously reduced to a smooth, flat face, by rubbing it on freestone. The japanned or varnished surface may afterwards be rubbed with pumice reduced to an impalpable powder, the workman using oil and leather to lay on the powder. The finishing may be given by oil and a piece of woollen only.

Where the varnish is thinner, and of a more delicate nature, it may be rubbed with tripoli, or rotten stone, in fine powder, finishing with oil as before. Where the ground is white, putty, or Spanish white, finely washed, may be used instead of rotten stone, of which the color might have some tendency to injure the ground.

Lackering.—Lackering consists in the application of transparent varnishes to metals, to prevent their tarnishing, or to give them a more agreeable color. When the color of the metal to be lackered is to be changed, the varnish is tinged with some coloring matter; but where preservation from rust, or tarnish, is the sole object, any of the transparent varnishes will answer, the best and hardest being used where the greatest durability is required.

Shell lac is the most common basis of the varnishes used in lackering. An imitation of gilding is effected by covering the surface of tin or lead with a clear varnish tinged with annotto, turmeric, or gamboge. The Chinese gilt paper appears to be made in this manner.

Gilding.—The process of gilding on metals, described in a former chapter, depends on a chemical union, or alloy, between the gold and the metal to which it is applied. But gilding, as it is commonly performed upon wood, leather, &c., is a mechanical process, and consists in cementing gold leaf upon surfaces, for which it has no affinity. In common *oil gilding*, the surface to be gilt is covered with an adhesive coating of paint or gold size, composed of yellow ochre ground in oil. When this is partially dried, so as to feel adhesive, the gold leaf is laid upon it and pressed down with cotton wool. When the whole surface is covered, it is left to dry, and the superfluous gold leaf brushed off. In *burnish gilding*, the surface to be gilt is first covered with a mixture of whiting and size, prepared by boiling shreds of parchment or skins, in water. This is rubbed smooth, and covered with a gilding size containing a little ochre or Armenian bole. This is suffered to dry, and is rubbed smooth with a linen rag. The gilding is then performed by moistening successively the parts of the sized surface with water, and applying the gold leaf before it becomes dry. When the work has become firm, it is burnished by rubbing it with a hard, polished substance, such as agate, dog's tooth, or steel.

Gilding on leather and on paper may be performed by applying gold leaf with gum arabic or size. The edges of paper and of books are gilded with a size composed of whites of eggs, beaten with three or four times their quantity of water, and mixed with a little Armenian bole. Bookbinders gild the leather of books by coating it two or three times with whites of eggs, and suffering it to dry. A minute quantity of tallow is then rubbed on, and the gold leaf laid loosely upon the surface. The stamps and letters are cut in brass; or printing types are used. These are moderately heated, as much as the leather will bear, and are then pressed upon the gold leaf, by which a por-

tion of gold corresponding to the letters is made to adhere; after which, the superfluous gold leaf is brushed off.

Shell gold is prepared by grinding up gold leaf with honey until it is completely subdivided ; the honey is then washed away with water, and the gold powder mixed with gum water or some other adhesive fluid. It is usually kept for use on shells, and is applied with a pencil or brush in the manner of common painting.

Photography.—This recent discovery, called also *heliography*, and *photogenic* drawing, has excited much interest among artists and men of science. The instrument or apparatus employed, has been called the *Daguerreotype* from its inventor, M. Daguerre, of Paris.

It has long been known that the sun's rays have the power of decomposing certain chemical compounds, in a very short time, and that this effect is produced most rapidly by the violet rays, and by rays which exist just beyond them in the prismatic spectrum, and that this property gradually diminishes as we advance to the red ray, at which it seems wholly wanting. Among the substances most sensitive to the chemical action of light, is the chloride of silver. It is at first perfectly white, but if exposed to the direct solar rays for a few minutes, it becomes violet, and at length almost black. The same effect is produced, more slowly, by exposure to indirect or diffused daylight.

If a substance of definite form, for instance, the leaf of a plant, be laid close upon a sheet of paper, previously prepared by coating it with a substance chemically sensible to light, and the whole be then exposed to the sun's rays, the surface of the paper will turn black, with the exception of the part covered by the leaf, which, being protected from the rays, will remain white, or nearly so, exhibiting the exact outline of the leaf. But as the leaf is not opaque, but partially transparent, some light will penetrate through its cells and pores, producing slight shades on the white surface beneath. These shades, necessarily corresponding to the veins and cells of the leaf, will produce a beautifully shadowed and reticulated appearance, corresponding exactly to that of the leaf itself.

It is well known that in the instrument called the camera obscura, a reduced image of natural objects is made to fall in shadow upon a plane surface. A desire has been excited among artists to preserve this image, by receiving it on a surface made chemically sensible to light, so that it might retain the difference of shade between the space covered by the image, and the unoccupied ground. Various experimenters, as M. Niepce in France, Mr. Talbot and others in England, have approximated towards this result, but complete success has only been attained by M. Daguerre, to whom the French Government has recently presented a reward, and whose method has been thus described, by M. Arago, before the Academy.

A copper sheet, plated with silver, well cleaned with diluted nitric acid, is exposed to the vapor of iodine, which forms the first coating, which is very thin, as it does not exceed the millionth part of a metre in thickness. There are certain indispensable precautions necessary to render this coating uniform, the chief of which is, the using of a rim of metal round the sheet. The sheet, thus prepared, is placed in the camera obscura, where it is allowed to remain from eight to ten minutes. It is then taken out, but the most experienced eye can detect no trace of the drawing. The sheet is now exposed to the vapor of mercury, and when it has been heated to a temperature of sixty degrees of Reaumur, or one hundred and sixty-seven Fahrenheit, the drawings come forth as if by enchantment. One singular fact in this process is, that the sheet, when exposed to the action of the vapor, must be inclined, for if it were placed in a direct position over the vapor, the results would be less satisfactory. The angle used is forty-five degrees.

After these three operations, for the completion of the process, the plate must be plunged into a solution of hyposulphite of soda. This solution acts most strongly on the parts which have been uninfluenced by light; the reverse of the mercurial vapor, which attacks exclusively that portion which has been acted on by the rays of light. From this it might, perhaps, be imagined, that the lights are formed by the amalgamation of the silver with mer-

cury, and the shadows by the sulphuret of silver formed by the hyposulphite. M. Arago, however, formally declared the positive inability of the combined wisdom of physical, chemical, and optical science, to offer any theory of these delicate and complicated operations, which might be even tolerably rational and satisfactory.

The picture now produced is washed in distilled water, to give it that stability which is necessary to its bearing exposure to light without undergoing any further change.

After his statement of the details of M. Daguerre's discovery, M. Arago proceeded to speculate upon the improvements of which this beautiful application of optics was capable. He adverted to M. Daguerre's hopes of discovering some further method of fixing not merely the images of things, but also of their colors ; a hope based upon the fact, that, in the experiments which have been made with the solar spectrum, blue color has been seen to result from blue rays, orange color from orange, and so on with the others. Sir John Herschel is sure that the red ray alone is without action. The question arose, too, whether it will be possible to take portraits by this method. M. Arago was disposed to answer in the affirmative. A serious difficulty, however, presented itself : entire absence of motion on the part of the object is essential to the success of the operation, and this is impossible to be obtained from any face exposed to the influence of so intense a light. M. Daguerre, however, believes that the interposition of a blue glass would in no way interfere with the action of the light on the prepared plate, while it would protect the sitter sufficiently from the action of the light. The head could be easily fixed by means of supporting apparatus. Another more important desideratum is, the means of rendering the picture unalterable by friction. The substance of the pictures executed by the Daguerreotype is, in fact, so little solid—is so slightly deposited on the surface of the metallic plate—that the least friction destroys it, like a drawing in chalk : at present, it is necessary to cover it with glass.*

* A varnish made of a solution of dextrine, protects the surface, but impairs the brilliancy of the picture.

From his numerous experiments on the action of light on different substances, M. Daguerre has drawn the conclusion, that the sun is not equally powerful at all times of the day, even at those instants when his height is the same above the horizon. Thus, more satisfactory results are obtained at six in the morning than at six in the afternoon. From this, too, it is evident, that the Daguerreotype is an instrument of exquisite sensibility for measuring the different intensities of light, a subject which has hitherto been one of the most difficult problems in Natural Philosophy. It is easy enough to measure the difference in intensity between two lights viewed simultaneously, but when it is desired to compare daylight with a light produced in the night—that of the sun with that of the moon, for example—the results obtained have had no precision. The preparation of M. Daguerre is influenced even by the light of the moon, to which all the preparations hitherto tried were insensible, even when the rays were concentrated by a powerful lens.

In physics, M. Arago indicated some of the more immediate applications of the Daguerreotype, independently of those which he had already mentioned in photometry. He instanced some of the most complex phenomena exhibited by the solar spectrum. We know, for example, that the different colored rays are separated by black transversal lines, indicating the absence of these rays at certain parts; and the question arises, whether there are also similar interruptions in the continuity of the chemical rays. M. Arago proposes, as a simple solution of this question, to expose one of M. Daguerre's prepared plates to the action of a spectrum; an experiment which would prove whether the action of these rays is continuous, or interrupted by blank spaces.

The degree of perfection which attends the process of photography exceeds that of any drawing, and is thus described by a witness.

"M. Daguerre puts a magnifying glass in our hand. We then see the minutest folds of drapery, the lines of a landscape, invisible to the naked eye. In the mass of buildings, accessories of all kinds, imperceptible accidents, of

which the view of Paris from the Pont des Arts is composed, we distinguish the smallest details, we count the stones of the pavement, we see the moisture produced by rain, we read the sign of a shop. Every thread of the luminous tissue has passed from the object to the surface retaining it. The impression of the image takes place with greater or less rapidity, according to the intensity of the light; it is produced quicker at noon than in the morning or evening, in summer than in winter."

It has been observed, that the cost of the plate must necessarily be considerable, and the chemical process requires nicety and skill; so that the expense of the photographic pictures will not be so trifling as might be supposed, especially when accidental failures are taken into account. By this process, it is to be borne in mind, the picture appears on the plate as it does on the camera, that is, with its forms and shadows painted dark on a white ground. In the simpler process, invented by Mr. Talbot, by which the solar rays act on a prepared paper, called *photogenic*, the light and shades of the real objects are reversed, and the picture is painted white on a dark ground. Mr. Talbot's method of preparing photogenic or sensitive paper, consists in washing fine writing paper over, first with a solution of nitrate of silver, then with bromide of potassium, and afterwards with nitrate of silver again; drying it at the fire after each operation. He also imitates etching on copperplate, by smearing over a piece of glass with a solution of resin in turpentine, and blackening it by the smoke of a candle: on this ground, the design is traced with the point of an etching needle, and the sensitive paper being placed behind the glass exposed to the sun, the rays of light, passing through the transparent lines, act upon the paper, and leave the design imprinted in a brown hue. The experiment can be repeated as often as may be desired. This last-mentioned process, however, is but printing by sunlight from etching on glass: it is curious enough, but far inferior to the perfection of M. Daguerre's process, by which the external picture is depicted in miniature, light for light, and shade for shade, to the minutest gradation of each. Color

alone is wanting in the results of this remarkable process.

OF CHANGING INTRINSIC COLOR.

The processes considered in the previous part of this chapter, are used to produce an external modification of color, and consist in mechanically covering the surfaces upon which they are applied. The remaining division includes those arts which depend more exclusively upon chemical processes, and which, by operating on the internal texture of bodies, produce a total and intrinsic change of color. Of this kind are the arts of bleaching, dyeing, and calico printing. The operations, however, which belong to these arts, are too extensive to be considered in all their details in this place.

Bleaching.—Bleaching is the process by which fibrous textures, such as linen, cotton, silk, &c., are deprived of their color, and rendered white. The coloring matter, which is inherent in vegetable fibres, appears to be of a resinous character, and the effect of the operation of bleaching is to dissolve, or discharge it. In manufactories of linen and cotton goods, the yarn or cloth passes through a number of successive processes, the principal of which are the *steeping*, in which the goods are fermented in an acescent liquid at a temperature of about one hundred degrees, Fahrenheit—the *bucking* and *boiling*, in which a hot alkaline ley is made to percolate through them for some time—the *souring*, performed with diluted sulphuric acid—the bleaching with *chlorine*, in which the stuff is exposed to the action of some compound of that substance, usually *chloride of lime*, called *bleaching salt*. Various mechanical operations, washings, and repetitions of the processes, are commonly practised to complete the discharge of the color. Formerly the process of bleaching was very tedious, and was effected by alkaline leys and by exposure to the sun and air, with frequent irrigations, for many weeks. The discovery of the bleaching power of chlorine has greatly abridged and simplified the process.

Chemists explain the effect of chlorine in bleaching,* by supposing that it unites with the hydrogen of the coloring matter, and forms muriatic acid, which again acts upon the color in its altered state. The acid may be detected in the altered coloring matter. In bleaching, which is performed by exposure to the air and moisture, it is supposed that oxygen combines with the coloring matter, and renders a portion of it more easy of solution, during the other parts of the process.

The fibres of wool and silk are not bleached by chlorine, but, after being deprived of the saponaceous or gummy matter, which adheres to them, are exposed to the fumes of burning sulphur to discharge their color.

Dyeing.—The art of dyeing consists in impregnating cloths and other flexible fabrics with coloring substances, in such a manner, that the acquired color may remain permanent under the common exposures to which the stuffs may be liable. It is effected by producing a chemical union between the material to be dyed and the coloring matter. It is found that different materials not only possess different attractions for dye stuffs, but that they absorb the coloring matter in different proportions. Wool appears in this respect to have the greatest attraction for coloring substances ; silk comes next to it, then cotton, and, lastly, hemp and flax.

Mordants.—The coloring substances used in dyeing have been divided by Dr. Bancroft into *substantive* and *adjective* colors. Substantive colors are those which communicate their tint immediately to the material to be dyed, without the aid of any third substance. Adjective colors require the intervention of a third substance, which possesses a joint attraction for the coloring matter and the stuff to be dyed. The substance capable of thus fixing the color, is called a *mordant*, and by Mr. Henry, a *basis*.

The agents, which are capable of acting in some way as mordants, are very numerous, including many oxides and salts. But those which are principally employed in

* Gay-Lussac, *Cours de Chimie*, Lec. 30, p. 2.—Ure's Notes to Berthollet, ii. 344.

practice, are the *acetate of alumina*, the *sulphate* or *acetate of iron*, and the *muriate of tin*. The substance to be dyed is first impregnated with the mordant, and then passed through a solution of the coloring matter. The mordant fixes the color, and, in many cases, alters or improves and heightens its tint.

Dyes.—The coloring substances, capable of being used as dyes, are very numerous ; but a few of the most important have, in practice, taken precedence of the rest. Indigo, madder, quercitron, and some of the woods, are consumed in vast quantities by dyers, and are capable of producing an indefinite variety of tints, under the action of different mordants. They are somewhat differently treated, according as the substance to be dyed is of wool, silk, or cotton.

Blue Dyes.—*Indigo* is the chief substance employed for giving the blue dye. The best indigo is obtained from a plant cultivated in warm climates, the *Indigofera tinctoria.* The plant is cut a short time before its flowering, and put into large vats covered with water, when fermentation spontaneously ensues, during which the indigo subsides in the form of a pulverulent, pulpy matter. Its color is at first green, but, by exposure to the air, it absorbs oxygen and becomes blue.

Indigo is a light, brittle substance, of a deep blue color, and without either taste or odor. At five hundred and fifty degrees Fahrenheit, it sublimes, forming a violet vapor with a tint of red, and condensing into long, flat, acicular crystals, which appear red by reflected, and blue by transmitted light. The process of subliming indigo is one of considerable delicacy, owing to the circumstance that the temperature at which it sublimes, is very near that at which it is decomposed. Indigo, in its dry state, may be preserved without change ; but when kept under water, it is gradually decomposed. It is quite insoluble in water and alcohol, and is attacked by the alkalies in a partial manner. Its only proper solvent is concentrated sulphuric acid. When indigo is put into this acid, a yellow solution is at first formed, which, after a few hours, acquires a deep blue color. If the indigo is pure, sulphurous acid is not

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generated, nor is the acid decomposed; but the indigo undergoes a change, for it is rendered soluble in water. To the indigo thus modified, Mr. Crum has applied the name *cerulin*, and he regards it as a compound of one atom of indigo and four atoms of water. This solution, properly diluted with water, is employed by dyers for forming what is called the *Saxon blue*. Mr. Crum has also described another compound of indigo and water, under the name of *Phœnecin*, because it acquires a purple color on the addition of a salt. It appears to consist of one atom of indigo and two atoms of water.

When indigo, suspended in water, is brought into contact with certain deoxidizing agents, it is deprived of oxygen, becomes green, and is rendered soluble in water, and still more in the alkalies. This effect is produced, for example, by sulphuretted hydrogen, by the hydrosulphuret of ammonia, by the protoxide of iron, precipitated by lime or potass, or by a solution of the sulphuret of arsenic in potass. On dipping cloth into a solution of deoxidized indigo, it receives a green tint, which becomes blue by exposure to the air. This is the usual method of dyeing blue by means of indigo, a color which adheres permanently to cloth without the intervention of a basis.

Woad is prepared from the leaves of the *Isatis tinctoria*, a plant cultivated in Europe. Gay-Lussac, and others, consider it chemically as a species of indigo. It is prepared by grinding, and several processes of fermentation. Cloth dyed in woad liquor, is at first green, but turns blue on exposure to the air, in the same manner which takes place with indigo.

Red Dyes.—The chief substances which are employed for giving a red dye, are madder, cochineal, archil, Brazil wood, logwood, and safflower, all of which are adjective colors.

Madder, which is one of the most valuable drugs in the art of dyeing, is the root of the *Rubia tinctorum*, a plant extensively cultivated in Europe, and particularly in Holland. It is properly classed with red dyes, but, by the use of different mordants, it is made to produce every

shade of red, purple, and even black. In calico printing, a piece may be stamped with several mordants, which are bases of different colors; and upon immersing it in a madder bath, as many colors will appear as there are mordants used. The quality of madder is said to be improved by age, provided it is kept packed in casks which exclude the air. Its quality is also affected by the mode of cultivating and curing it, and the judgement which is used in separating the samples.

Cochineal is obtained from an insect, already mentioned, which feeds upon the leaves of several species of the cactus, and which is supposed to derive this coloring matter from its food. It is very soluble in water, and is fixed on cloth by means of alumina or the oxide of tin. Its natural color is crimson; but when the bitartrate of potass is added to the solution, it yields a rich scarlet dye. Cochineal, according to Pelletier and Caventou, is composed of, 1. Carminium, which is the name given to the coloring matter. 2. A peculiar animal matter. 3. A fatty substance. 4. Salts of lime and potass.

Archil.—The dye called *archil*, is obtained from a kind of lichen, (*Lichen roccella*) which grows chiefly in the Canary Islands, and is employed by the Dutch in forming the blue pigment called *litmus* or *turnsol*. The coloring ingredient of litmus is a compound of the red coloring matter of the lichen and an alkali; and hence, on the addition of an acid, the coloring matter is set free, and the red tint of the plant is restored. Litmus is not only used as a dye, but is employed by chemists for detecting the presence of a free acid.

Logwood is a dense, heavy wood, derived from the *Hæmatoxylum Campechianum*, which grows in the tropical parts of America. A decoction made from this wood, is of a fine red, inclining a little to violet or purple. This, if left to itself, becomes in time yellowish, and at length black. The violet color of logwood is fixed by alum, and a blue is obtained from it by verdigris. But the great consumption of logwood is for blacks, to which it gives a peculiar depth, and velvety lustre. The coloring principle of logwood has been procured in a sep-

arate state by M. Chevreul, who has applied to it the name of *hematin*. It is obtained in crystals, by digesting the aqueous extract of logwood in alcohol, and allowing the alcoholic solution to evaporate spontaneously.

Brazil wood is the heart, or central part of the *Cæsalpinia echinata*, a large tree of Brazil. It produces very lively and beautiful red tints, with solutions of alumina and tin, but they are deficient in permanency. *Sappan* wood, brought from the East Indies, and *Nicaragua wood*, or *Peachwood*, from Central America, are also said to be species of Cæsalpinia, and resemble Brazil wood in their properties, but yield a smaller amount of coloring matter. *Braziletto* and *Camwood* are among the poorest of the red dyes.

Safflower is the dried flowers of the *Carthamus tinctorius*, and affords a bright but fugitive red. See *Rouge*.

Yellow Dyes.—The chief yellow dyes are the quercitron bark, turmeric, hickory, weld, fustic, and saffron. They are all adjective colors.

Quercitron bark, which is one of the most important of the yellow dyes, is an extract made from the bark of the *Quercus tinctoria*, or common black oak of the United States, and was introduced into notice by Dr. Bancroft. With a basis of alumina, the decoction of this bark gives a bright yellow dye. With the oxide of tin, it communicates a variety of tints, which may be made to vary from a pale lemon color to deep orange. With the oxide of iron, it gives a drab color.

Hickory.—Several species of American walnut or hickory, particularly the *Juglans*, or *Carya alba*, yield a yellow dye from their bark, leaves, and rinds, resembling quercitron, but less abundant in quantity.

Weld is derived from a European plant, *Reseda luteola*. When fixed with a basis of alum, it gives a lively and permanent yellow.

Fustic is the wood of the *Morus tinctoria*, a tree of the West Indies. It affords, with an aluminous basis, a less brilliant, but more durable yellow, than the preceding articles. It is also employed to produce certain greens and drab colors.

Annotto, otherwise called *Rocou*, is a soft substance prepared from the seeds of the *Bixa orellana*, a shrub of tropical America. The coloring matter is combined with a resin which renders it difficult of solution in water. An alkali facilitates the solution and improves the color.

Turmeric is the root of the *Curcuma longa*, a native of the East Indies. Paper, stained with a decoction of this substance, constitutes the turmeric or curcuma paper employed by chemists as a test of free alkali; by the action of which it receives a brown stain.

Saffron.—The coloring ingredient of *saffron* (*Crocus sativus*) is soluble in water and alcohol, has a bright yellow color, is rendered blue and then lilac by sulphuric acid, and receives a green tint on the addition of nitric acid. From the great diversity of colors which it is capable of assuming under different circumstances, M. M. Bouillon, Lagrange, and Vogel, have proposed for it the name of *Polychroite*.

French Berries.—The unripe berries of the *Rhamnus infectorius* afford a lively but fugitive yellow.

Black Dyes.—The black dye is made of the same ingredients as writing ink, and therefore contains usually a compound of the oxide of iron with gallic acid and tannin. From the addition of logwood and acetate of copper, the black receives a shade of blue.

Galls.—The common nutgall is an excrescence produced upon an Asiatic species of oak, (*Quercus infectoria*) by the puncture of an insect, a species of *cynips.* It contains tannin, gallic acid, and, according to Dr. Bancroft, a coloring matter distinct from these. Galls produce a black color with salts of iron, well known as the basis of writing ink.

Maple.—The common red maple of this country, (*Acer rubrum*,) when applied with the sulphate or acetate of iron, produces, according to Dr. Bancroft, a more intense and perfect black than any of the common vegetable dyes. With the aluminous basis, it produces a lasting cinnamon color, both on wool and cotton. Both the bark and leaves may be used.

Butternut.—The bark of the butternut (*Juglans ca-*

thartica) affords a durable brown upon cotton with an aluminous basis, and upon wool without any mordant.

By the dexterous combination of the four leading colors, blue, red, yellow, and black, all other shades of color may be procured. Thus green is communicated by forming a blue ground with indigo, and then adding a yellow by means of quercitron bark.

One of the latest improvements in the art of dyeing, consists in the employment of colors derived from the mineral kingdom. Prussian blue, orpiment, chromate of lead, and other mineral compounds, have, by appropriate processes, been made to communicate their colors to different stuffs. An abstract of the processes is given in Ure's notes to Berthollet on dyeing.

Calico Printing.—Calico printing is a combination of the arts of engraving and dyeing, and is used to produce upon woven fabrics, chiefly of cotton, a variety of ornamental combinations, both of figure and color. In this process, the whole fabric is immersed in the dyeing liquid, but it is previously prepared in such a manner, that the dye adheres only to the parts intended for the figure, while it leaves the remaining parts unaltered. In calico printing, adjective colors are most frequently employed. The cloth is prepared by bleaching and other processes, which dispose it to receive the color. It is then printed with the mordant, in a manner similar to that of copperplate printing, except that the figure is engraved upon a cylinder, instead of a plate. The cylinder, in one part of its revolution, becomes charged with the mordant mixed to a proper consistence with starch. The superfluous part of the mordant is then scraped off by a straight steel edge, in contact with which the cylinder revolves, leaving only that part which remains in the lines of the figure. The cloth then passes in forcible contact with the other side of the cylinder, and receives from it a complete impression of the figure in the pale color of the mordant. The cloth is then passed through the coloring bath, in which the parts previously printed, become dyed with the intended color. When it is afterwards exposed, and washed, the color disappears from those parts which are

not impregnated with the mordant, but remains permanently fixed to the rest. When additional colors are required, they are printed over the rest with different mordants, suited to the color intended to be produced. This secondary printing is in most instances performed with blocks, engraved in the manner of wood cuts, and applied by hand to the successive parts of the piece.

In some articles, white spots upon a dark ground are produced by covering the parts with wax, tallow, pipe clay, or other materials, which prevent the contact of the color. Sometimes the color is discharged in places, by the application of chlorine. A preparation of one of the salts of copper, applied in spots, or figures, has the effect to oxygenate indigo, so as to render it insoluble, and consequently incapable of dyeing these spots, when the stuff is immersed. To these and similar processes, the name of *resist work* has been given.

Fast Colors.—The following are the dye stuffs used by the calico printers for producing fast colors.* The mordants are thickened with gum, or calcined starch, and applied with the block, cylinder, plates, or otherwise.

1. *Black.* The cloth is impregnated with acetate of iron (iron liquor) and dyed in a bath of madder and logwood.

2. *Purple.* The preceding mordant of iron, diluted; with the same dyeing bath.

3. *Crimson.* The mordant for purple, united with a portion of acetate of alumina, or red mordant, and the above bath.

4. *Red.* Acetate of alumina is the mordant, and madder is the dye stuff.

5. *Pale red* of different shades. The preceding mordant diluted with water, and a weak madder bath.

6. *Brown* or *Pompadour.* A mixed mordant, containing a somewhat larger proportion of the red than of the black; and the dye of madder.

7. *Orange.* The red mordant; and a bath first of madder, and then of quercitron.

* Ure's Dictionary.

8. *Yellow.* A strong red mordant; and the quercitron bath, whose temperature should be considerably under the boiling point of water.

9. *Blue.* Indigo, rendered soluble and greenish-yellow colored, by potash and orpiment. It recovers its blue color, by exposure to air, and thereby also fixes firmly on the cloth. An indigo vat is also made, with that blue substance, diffused in water with quicklime and copperas. These substances are supposed to deoxidize indigo, and at the same time to render it soluble.

Golden-dye. The cloth is immersed alternately in a solution of copperas and lime-water. The protoxide of iron precipitated on the fibre, soon passes, by absorption of amospherical oxygen, into the golden-colored deutoxide.

Buff. The preceding substances, in a more dilute state.

Blue vat, in which white spots are left on a blue ground of cloth, is made, by applying to these points a paste composed of a solution of sulphate of copper and pipe clay; and after they are dried, immersing it stretched on frames for a definite number of minutes, in the yellowish-green vat, of one part of indigo, two of copperas, and two of lime, with water.

Green. Cloth dyed blue, and well washed, is imbued with the aluminous acetate, dried, and subjected to the quercitron bath.

In the above cases, the cloth, after receiving the mordant paste, is dried, and, after some preparation, put into the dyeing vat of copper.

Fugitive Colors.—All these colors are given, by making decoctions of the different coloring woods; and receive the slight degree of fixity they possess, as well as great brilliancy, in consequence of their combination or admixture with the nitro-muriate of tin.

1. *Red* is frequently made from Brazil and peachwood.

2. *Black.* A strong extract of galls, and deuto-nitrate of iron.

3. *Purple.* Extract of logwood and the deuto-nitrate.

4. *Yellow.* Extract of quercitron bark, or French berries, and the tin solution.

5. *Blue.* Prussian blue and solution of tin.

Fugitive colors are thickened with gum tragacanth, which leaves the cloth in a softer state than gum senegal; the goods being sometimes sent to market without being washed.

Works of Reference.—Tingry's Painter's and Varnisher's Guide, 8vo. translated 1816;—Elmes's Dictionary of Fine Arts, 8vo. 1826;—James's Panorama of Science and Art, 2 vols. 8vo. 1816;—Bancroft on Permanent Colors, 2 vols. 8vo. 1814;—Berthollet, Elements of the Art of Dyeing, translated by Ure, 2 vols. 8vo. 1824; Gay-Lussac, *Cours de Chimie*, 2 vols. 8vo. 1828;—Brande's Chemistry, 1820;—Turner's Chemistry, 1828;—Parke's Chemical Essays, 1823;—Ure's Dictionary;—also Philosophy of Manufactures, by do. 8vo. 1835;—Vitalis, *Cours élémentaire de teinture*, 1823.

CHAPTER VII.

THE ARTS OF WRITING AND PRINTING.

Letters, Invention of Letters, Arrangement of Letters, Writing Materials, Papyrus, Herculaneum Manuscripts, Parchment, Paper, Instruments, Ink, Copying Machines, Printing Types, Cases, Sizes, Composing, Imposing, Signatures, Correcting the Press, Press Work, Printing Press, Stereotyping, Machine Printing. History.

Letters.—The arts of writing and printing, although comparatively simple in their processes, are superior to most other arts in the importance of their consequences. Before the invention of letters, the growth of knowledge was opposed by insurmountable obstacles. Tradition, which was the earliest mode of transmitting knowledge, depended upon the memory and the will of individuals, and was of course uncertain of continuance. The principal adventitious aids brought to the assistance of traditionary knowledge, were the erecting of monuments, the celebration of periodical days or years, the use of poetry, a language more captivating and more easily remembered than mere narration of facts; and finally, an approach to written characters in symbolical drawings and hiero-

glyphic sketches.* All these methods, however, have failed in the object for which they were intended. The ancient founders of many stupendous structures have not been able to convey to us their names, and the productions of the earliest sages and poets can never be appreciated from acquaintance. History must have remained uncertain and fabulous, and science been left in perpetual infancy, had it not been for the invention of written characters.

Invention of Letters.—The credit of the first introduction of letters, was claimed by the Egyptians and Phœnicians, Jews, Chinese, and other nations. Their origin is extremely ancient, and of course preceded all authentic history which was not inspired. If we believe Pliny, sixteen characters of the Grecian alphabet were introduced by Cadmus, the Phœnician, fifteen hundred years before Christ. Four more were added by Palamedes, during the Trojan war, and four afterwards by Simonides. It is not probable, however, that the Greek was the oldest alphabet. Mr. Astle considers the Phœnicians as having the strongest claim to be considered the first inventors of letters.

Arrangement of Letters.—The mode of arranging letters has been subject to considerable variation, some nations having written in perpendicular lines, others, from right to left, and others, in lines alternately reversed, as in the bustrophedon of the ancient Greeks.† The mode of writing from left to right, now generally pursued, is the

* The recent investigations of M. Champollion have led to the discovery that a great part of the hieroglyphic characters upon the antiquities of Egypt are in reality the letters of an alphabet; and considerable progress was made by him, in deciphering their import.

† The bustrophedon was disused by the Greeks about four hundred and fifty years before the Christian era; but a similar method appears to have been in use, among the Irish, at a much later period. The following example of the Greek bustrophedon is from an inscription on a marble in the national museum at Paris.

ΝΕΚΗΘΕ ΝΕΜ ΣΟΛΛΥ
ΑΡΙΣΤΟΚΥΔΕΣ ΝΟΗΣΕΝ

em decalp sullyH
Aristocydes designed me.

most natural; because the hand, as it advances in this direction, leaves constantly uncovered that portion of the page upon which writing has been made.

Writing Materials.—The most ancient materials employed for writing, appear to have been the surfaces of stones and bricks. The ten commandments were written upon stone, and the arrow-headed alphabet, as it is called, belonging to an extinct language, is only known to us by the pages of inscriptions which remain on the Babylonian bricks. After these, plates of metal, of various kinds, were employed. The Romans wrote upon tables of brass thinly coated with wax, using an iron pencil with a sharp point denominated *Stylus*. Lead was also used by them; and at the siege of Modena, a correspondence was carried on by Decimus Brutus, and the consul Hirtius, upon plates of lead. Pausanias mentions books of Hesiod, and Pliny speaks of public records, inscribed on the same material. A less durable, but more cheap receptacle for written characters, was found in the leaves of trees, and their inner bark, denominated *liber* by the Latins. These were used for the more temporary or perishable writings.*

Papyrus.—As the literature of antiquity advanced, it became necessary to find a material adapted for works of magnitude, which, besides permanency and enlarged size, should have a fineness of texture sufficient to permit a large surface to be folded into a compact form. A species of reed, growing in Egypt, was found capable of being manufactured into a substance of this sort. Sheets

* Pliny says that tables of wood were in use for writing before the time of Homer. In the Slonian library at Oxford, there are some specimens of ancient Arabic writing on boards about two feet long and six inches wide.

The edicts of the Roman Senate were written on tablets of ivory, thence denominated *libri elephantini*.

According to Pliny, the most ancient mode of writing, was upon the leaves of palm trees, afterward upon the inner bark of trees. This method is still common in Tanjore, and some other parts of the East Indies, where the Palmyra leaf is used.

The old Egyptians frequently wrote on linen, and specimens of this kind are sometimes found enclosed in the garments or swathing clothes of mummies.

and rolls were prepared from it of the finest texture, and of any dimensions, and it became the receptacle on which a great part of the ancient manuscripts were written. This was the celebrated Egyptian papyrus. The discovery of its manufacture, though it afforded a substance far inferior to modern paper, was nevertheless a great auxiliary to ancient learning, and became the means of a much more extensive multiplication of manuscripts than could have taken place had it remained unknown. The papyrus was an aquatic reed growing on the banks of the Nile.* The manufacture of paper was performed by divesting this reed of its outer covering, and then carefully separating the internal membranes or laminæ by the point of a needle or knife.† These laminæ were spread parallel to each other on a table, having their edges in contact, in sufficient numbers to form a sheet. A second stratum was then laid, with the strips crossing those of the first at right angles. The whole was moistened with water, and subjected to pressure between two polished surfaces. Upon drying, the mass was found agglutinated into a smooth and uniform sheet. The adhesion of the strips of papyrus together was doubtless owing to the glutinous juice of the reed, though the Romans, who were ignorant of the Egyptian mode of manufacturing it, attributed this effect to a peculiar quality in the waters of the Nile. The most delicate paper, which was made from the inner membranes or tunics of the reed, was rendered extremely white, and polished by rubbing it with a shell, or tooth of an animal.

Herculaneum Manuscripts.—The papyrus continued in use as late as the tenth or twelfth century, when it was superseded by parchment and cotton paper. A few ancient manuscripts written on it are preserved as curiosities, in different libraries of Europe, though they are less numerous than those of parchment and vellum. The most interesting collection of papyri is undoubtedly that found at Herculaneum, and was probably buried with that city

* Cyperus papyrus. L.

† The delicate substance now imported from India under the name of *rice paper*, is a cellular membrane of the *Artocarpus incisifolia*, or bread-fruit tree.—*Brewster's Journal*, iii. 136.

in an eruption of Vesuvius, which happened during the reign of Titus. In the excavations which the moderns have made into the earth which covers that city, these rolls of papyri, nearly seventeen hundred in number, were found in a house, the roof and floors of which had been crushed in by the substances ejected from the volcano. The rolls were found in a state so near to decomposition that the least violence causes them to break and crumble; their color is so nearly black that the characters are distinguishable from the paper only by a slight shade of difference; and the whole roll is cemented together, so as not to be separable into layers without great difficulty. This state has been supposed to be produced by the carbonization, or converting into coal, of the papyri, by the heat of the ashes and lava, in which they were buried. Sir Humphrey Davy, however, has given a different opinion of the state of these manuscripts. He supposes that their present condition is not the result of carbonization or of heat applied to them, but is the consequence of their remaining for so many ages under ground, until the vegetable matter of which they are composed, has undergone a spontaneous change, and become converted into a substance analogous to peat, or Bovey coal. This conclusion is the result of chemical examination, and is likewise inferred from the fact that some specimens of gilding, and of vermilion, which remained on the walls of the apartment, were not changed in color, which could not have been the case, had the heat been sufficient to convert vegetable matter into charcoal.

About ninety of these manuscripts have been unrolled by a very tedious process, which consists in glueing pieces of goldbeaters' skin to the outside of the rolls, and suffering them to dry on. They are then gradually raised by means of screws, lifting with them a layer of the papyrus, which is copied and the process renewed. Several days, in this way, are requisite for a single page. Sir Humphrey Davy supposed a more expeditious way might be adopted, by subjecting the rolls to the action of a chemical solvent, capable of destroying the adhesion of the folds to each other. He supposes that of the manu-

scripts which remain, not more than from eighty to one hundred and twenty are in a state to be unrolled, the rest being too much defaced, by crushing or otherwise, to render it probable they will ever be deciphered.

Parchment.—Next to the papyrus, the skins of animals, in the form of parchment and vellum, were extensively used for writing, by the ancients, from a remote period. When Eumenes, or Attalus, attempted to found a library at Pergamus, two hundred years before Christ, which should rival the famous Alexandrian library, one of the Ptolemies, then king of Egypt, jealous of his success, made a decree prohibiting the exportation of papyrus. The inhabitants of Pergamus set about manufacturing parchment as a substitute, and formed their library principally of manuscripts on this material; whence it was known among the Latins by the name of *Pergamena.* The term *membrana* was also applied by them to parchment.

Paper.—Paper like that used at the present day, composed of flexible fibres reduced to a pulp by minute division, and cemented into sheets by means of size or glue, began to be known in the East in the beginning of the tenth century. It was first composed of cotton or silk, and called *bombycina*, and was not made from linen rags until the fourteenth century. Coarse brown paper was first manufactured in England, in 1588; writing and printing paper in that country not till 1690, previously to which, it was imported from the continent.

Instruments.—While writing was practised upon hard substances, as stone and metal, a hard metallic point was the instrument with which letters were formed. The *stylus*, which the Romans employed for writing on brass tablets covered with wax, was acute at one end for writing, and flattened or blunt at the other, for erasing what was written. For writing in colored fluids, or ink, the *calamus* was used, a reed sharpened at the point, and split like our pens. Quills were not introduced till the fourth or sixth century.*

* The earliest notice of the use of quills, is by an anonymous author of the life of Constantius, who says that Theodoric, the Ostrogothic

Some of the eastern nations still write with reeds, canes, and bamboos, instead of quills. The Chinese write with small brushes like camels' hair pencils.

Inks.—The *ink* of the ancients consisted of a carbonaceous substance, such as lampblack, soot, or pulverized coal, united with a viscid or gummy liquid. The black liquor of the cuttle fish (*Sepia*) was sometimes employed. Colored inks of vermilion, red lead, and purple, were also used. The eastern emperors signed their edicts with red ink, the use of which was prohibited to others, under pain of death.

Modern ink is essentially a tanno-gallate of iron suspended by mucilage. It may be made from salts of iron, and infusions of various astringent vegetables. But as many products of this kind are apt to fade by time, it is not safe to trust to any which have not had the testimony of long experience in their favor. The best materials are the nutgall and sulphate of iron, with gum arabic. Other ingredients are sometimes added, such as logwood, sulphate of copper, and sugar. When ink fades, it is commonly from the fugitive nature of the gallic acid and tannin; and it may be revived by moistening the page with a fresh infusion of galls. When ink grows thin from freezing, or dilution, so that its particles subside, they may again be suspended, by agitating it with sugar, or gum. If writing with common ink has been obliterated by chlorine, it may be again rendered legible, by the vapor, or solution, of sulphuret of ammonia. *Indelible* ink is produced by writing with dissolved nitrate of silver on a surface impregnated with carbonate of soda.

Copying Machines.—Various modes have been devised, for making extemporaneous copies of written pages. Dr. Franklin's method consisted in covering the writing, while yet moist, with fine powdered emery; and afterwards passing the sheet through a press, in contact with a plate of pewter, or copper; which thus became marked

king of Rome, was so illiterate, and so dull of intellect, that, during the ten years of his reign, he could not learn four letters to sign at the bottom of his edicts; so that they were cut for him in a plate of gold, through which he traced the letters with a quill. One of the oldest certain notices of the use of quills, is by Isidore, who died in 636.

with the letters, so as to yield impressions, as in the common mode of copperplate printing. Mr. Watt's *copying machine* consists of a press, in which a thin, bibulous paper, previously moistened, is forced into close contact with the page, while newly written. A part of the ink, sufficient to produce legible characters, is thus transferred to the thin paper. The writing is of course reversed, but the thinness of the paper permits it to be read on the opposite side, which restores the order of the letters. Mr. Hawkins's *polygraph* is a machine carrying two or more pens in different places, which are so connected as to pursue a similar path with each other, and execute two or more copies at once. Lithography likewise offers a ready method of multiplying copies.

PRINTING.

The art of printing, as it is now practised, by the composition of movable types, is so simple and obvious in its principles, that it is truly wonderful the process was not earlier known. The ancients many times made near approaches to the discovery, but, by some singular fatality, they were kept from its profitable use. Arts far more curious, and sciences far more difficult, were known, and carried to perfection, by the patient industry of the ingenious and enterprising in former times. But this art, which was to give permanency to all the rest, and which now seems to be at the root of all human knowledge, was never in useful operation in Europe until three or four centuries ago.

Types.—Printing at the present day is executed with movable types, which are oblong square pieces of metal, each bearing a letter in relief at one extremity. The metal of which they are made, is an alloy, which consists essentially of lead and antimony. The lead is selected in preference to other metals, because it is fusible at a low temperature, and retains accurately the shape it receives from the mould. But as lead alone is too soft to sustain the friction and pressure to which it is liable in use, about a fifth part of antimony is added. This gives it a superior hardness when cast; and as this alloy has

the property of shrinking less than most other metals as it cools, the type receives all the sharpness and finish, which it can acquire, by filling every part of the mould. In making types, the letter is first cut by an artist upon the end of a steel punch, answering to the shape of the intended type. This punch is driven into a piece of copper, which forms the *matrix* or bottom of the mould intended to produce the letter. As many varieties of punches must be made of steel, as there are sizes and species of characters required. In casting, the types are formed with great rapidity, owing to the quickness with which the metal cools. An expert operator will cast two or three thousand types in a day. Some machines have been introduced, for casting types, which operate with much greater rapidity. The characters upon types are of course reversed, so that in arranging them for the press, the *compositor*, or printer who sets the types, begins at the right hand of each line.

Case.—Before the types are applied to use, they are arranged in the cells or compartments of a long wooden receptacle, called a *case;* each species of letter, character, or space, by itself. In arranging the compartments, the collections of letters do not succeed each other in alphabetical order, nor are they all of equal size. Those letters which occur most frequently in printing, are required in greater numbers. They are therefore made to occupy the largest compartments, and are placed nearest to the compositor. Thus the letter e, which is of frequent occurrence, fills a large compartment, and is near the compositor, while the letter x, which occurs much less frequently, is provided in small numbers, and placed at the extremity of the case. In a *bill* or collection of types of the size called pica, weighing in all 800 pounds, the number of the letter e is 12000; of t, 9000; of a, 8500; of i, n, o, and s, 8000 each; of c, there are 3000; of b, 1600; k, 800; x, 400; z, 200. This is for the English language. In other languages, the comparative frequency must be different.

Sizes.—Different names are given to the various sizes

of types, of which the following are most employed in book printing.

English,	a b c d e f g h i j k l m n o p q r s t
Pica,	a b c d e f g h i j k l m n o p q r s t u v
Small Pica,	a b c d e f g h i j k l m n o p q r s t u v w x y
Long Primer,	a b c d e f g h i j k l m n o p q r s t u v w x y z
Bourgeois,	a b c d e f g h i j k l m n o p q r s t u v w x y z
Brevier,	a b c d e f g h i j k l m n o p q r s t u v w x y z
Minion,	a b c d e f g h i j k l m n o p q r s t u v w x y z
Nonpareil,	a b c d e f g h i j k l m n o p q r s t u v w x y z
Pearl,	a b c d e f g h i j k l m n o p q r s t u v w x y z
Diamond,	a b c d e f g h i j k l m n o p q r s t u v w x y z

Composing.—The compositor is first provided with an instrument called the *composing stick.* This is a plate, commonly of iron or brass, surrounded with ledges, one of which is movable, so that the length of the lines may be adjusted to the width of the page. The compositor selects from their places the letters, successively, to constitute the first word, which are arranged in an inverted order from that in which they are to appear on the printed page, beginning at the right. At the end of each word, a *space* is inserted, to produce a separation between this word and the next following. The spaces, of which there are various kinds, differently named from their width, are blunt types, bearing no letter on their extremities. In printing, they do not come up to the surface, and of course yield no impression. As the beauty of the page depends upon the evenness of the margin produced by the equality of the lines, these spaces are used to swell out the shorter lines and bring them to an equality with the rest. When one line is finished, the printer shifts the *rule* from below it to the top, and commences setting the types for a second line. The rule is a thin brass, tin, or iron, plate, used to make the types slide easily, and not catch upon the line below them. At the end of a paragraph, the line is spaced out with *quadrats,* which are spaces of a large size.

The quickness with which an expert compositor advances in his work, is greater than would appear possible from a first consideration of the subject. The familiarity with the situations of the letters and their arrangement, produced by long habit, is such, that to select the types and place them, does not require a thought to be bestowed

on the process. It is only necessary to perceive the meaning of each word, and the putting it together follows as mechanically as writing. It is even possible for a printer to compose in the dark, for the exact situation of each letter in the case before him being known, and the upper side of each being known by notches in the type, they can be selected and arranged by the sense of feeling alone.

Imposing.—When a sufficient number of lines, as six or eight, are formed in the composing stick, they are *emptied* into another instrument called the *galley*, which is a flat board or plate, partly or wholly surrounded by a rim. In this galley, the types are accumulated, generally in the form of long columns, which are afterwards divided into pages, each page being tied together with a string to prevent the types from falling asunder. When a sufficient number of pages are completed to constitute what is called a *form*, or, in other words, to fill one side of a sheet, they are arranged upon an *imposing stone*, and strongly *locked up*, or wedged together, in an iron frame, denominated a *chase*, to prepare them for the press.

Signatures.—A sheet intended for a folio, has two pages on a side, and will form two leaves. A quarto has four; an octavo, eight; a duodecimo, twelve, &c. These pages are so arranged in the form, that in the impression they will assume their true order, after the sheet is folded. The sheets are marked at the bottom of certain pages with successive numbers, or capital letters; the object of which is, to afford the necessary instructions for the order of folding and gathering them. These are called *signatures*.

Correcting the Press.—The first impression taken from the types is called a *proof*. This is carefully read over, and the errors and inaccuracies marked. To correct them, the wedges or *quoins* are knocked out, so as to loosen the types; the erroneous letters are drawn out, and the proper ones substituted, and the whole is again wedged into the frame.

Many of the errors of the press, which remain uncorrected in books, arise from a want of understanding between the author, or correcter, and the printer, in the characters

used in correction. It is not enough that the author should detect these errors and note them in the margin. He must express, by intelligible marks, how these defects are to be altered; and unless he uses such marks as are employed by printers themselves, his attempts at correctness will be defeated. Every person who has occasion to appear in print, should first know how to correct the press.*

The following signs for correcting the press, are employed by printers themselves.

When a wrong letter is discovered, a line is drawn through it, and the true letter is written in the margin, thus:

To be, or not to be, that i/ the question. *s*

If a letter is found to be omitted, a caret is placed under its place, and the letter written in the margin, thus:

To be, or not to be, th‸t is the question. *a*

If a superfluous letter is detected, it is crossed out, and a character which stands for *dele*, (blot out or expunge,) introduced in the margin.

To be, or not to~~o~~ be, that is the question.

If two words are improperly joined together, a character indicating a space, is used.

To be, or not to‸be, that is the question. #

If words are placed too far apart, a horizontal parenthesis is placed over and between them, and a perpendicular parenthesis in the margin, thus:

To be, or not‿to be, that is the question. ( )

* If the error is confined to a letter or word, it is easily corrected. But if it involves the addition or erasure of a sentence or a number of lines, the correction is more difficult. The whole form must be deranged, and as the adding or expunging of lines affects the length of the page, it must be adjusted at the expense of the next following page; so that all the subsequent pages may be disturbed, before the necessary correctness is obtained. An author who corrects the press for his own works, will very much abridge the labor of the printer, if, in all cases of an erased word, he will substitute another of nearly the same length in its neighborhood, or, if a new word is added, by striking out one in the paragraph which can be better spared.

If syllables of the same word are improperly separated, they are joined by a horizontal parenthesis.

To be, or not to be, that is the ques tion.

When words are found to be transposed, they are connected by a curved line, and the letters *tr.* (transpose) written in the margin.

To be, or not to be, is that the question. *tr.*

When a letter is inverted, it is expressed by a character of this sort in the margin:

To be, or not to be, that is the question.

Marks of punctuation are generally placed before a short stroke, thus:

The apostrophe and mark of quotation are marked as in the margin:

The period and hyphen are enclosed in circles, thus:

Words intended to be printed in italics, are marked beneath with a single line; if in small capitals, with two lines; and if in large capitals, with three. Thus, a line marked in this manner,

Oh thou, in Hellas deemed of heavenly birth,

would be printed thus:—

OH THOU, in HELLAS deemed of *heavenly* birth.

In correcting with these marks, the abbreviations, *Ital.*, *Rom.*, *Caps.*, &c., should also be written in the margin.

Corrections themselves sometimes require to be corrected. Thus, if a word has been improperly altered, and it is afterwards thought best to retain it, dots are placed beneath, and the word *stet* (let it stand) written in the margin.

When lines are crooked, or letters have been disturbed from their places, or blemishes appear, it is sufficient to call the attention of the printer, by a dash of the pen, at the place.

Press Work.—After the sheet is corrected and revised, it is then ready for the press, to which it is accordingly transferred. The ink is first applied over the whole surface of the types; the paper, previously moistened, is then laid down upon them, the whole is passed under the press, and the paper being brought into forcible contact with the types, receives from their surface the ink necessary for a distinct impression. Printers' ink is composed chiefly of lampblack and oil inspissated by boiling and burning. Oil is necessary, that the ink may not dry during the operation, and it is reduced by boiling, to prevent it from spreading on the paper. It is applied to the types by large elastic balls made of leather and stuffed with wool, or by elastic rollers, like those used in printing machines.

Printing Press.—The common or old printing press, derives its power from a screw, which is turned by a lever, and acts perpendicularly on the *platten*, or level part, which transmits the pressure. Various improvements have been made in the printing press, by Lord Stanhope, and other inventors, in most of which a cast-iron frame is substituted for a wooden one, being more inflexible; and a combination of levers is used, so arranged as to cause the platten to descend with decreasing rapidity, and consequently with increasing force, till it exerts the greatest power at the moment of contact of the paper with the types.

Stereotyping.—In stereotype printing, instead of movable types, blocks or plates are used, each containing all the characters requisite to form a page. The process of stereotyping is simple. A page of any work proposed to be stereotyped, is set up in the usual manner with movable types. From this page, when corrected, a mould in plaster is taken off, and from this mould, a plate of type-metal is cast, having all the characters in relief, and being a fac-simile of the original page. From this plate, the printing is executed, and there must be, of course, as many plates cast, as there are pages in the book to be printed. It will thus be seen, from the accounts already given, that the stereotyped

letter press constitutes the sixth time that the character has been formed, viz., 1, in the steel punch; 2, in the matrix; 3, in the movable type; 4, in the plaster cast; 5, in the stereotyped character; and 6, in the printed page.

The plaster used for forming the moulds is pulverized gypsum, dried by heat, and mixed with water; to which is added a little whiting to diminish the tendency of the plaster to shrink and crack. After the form of types has been slightly oiled, and surrounded with a metal frame, fluid plaster is applied over the surface with a brush or roller, so as to fill every cavity of the letters. A quantity of plaster mixed with water to the consistence of cream, is then poured on the type, and the superfluous part scraped off. When the plaster has become hard, it is lifted off by the frame, and detached from it. It is then baked to dryness in an oven, and when quite hot, it is placed in an iron box or casting pot, which has also been heated in an oven. The box is now plunged into a large pot of melted type-metal, and kept about ten minutes under the surface, in order that the weight of the metal may force it into all the finer parts of the letters. The whole is then cooled, the mould broken and washed off, and the back of the plate turned smooth in a lathe, or planed by a machine. The earlier stereotype founders, as Didot and others, formed their moulds with a soft metal, or a metal at the point of congelation, instead of plaster.

Stereotype printing is chiefly useful for standard and classical works, for which there is a regular demand, and of which the successive editions require no alteration. It is now executed with such increased economy, as to be applicable to works even of less durability. A saving, both of time and interest, is made by the circumstance that the types are immediately dispensed with, and that it is not necessary to strike off larger editions than the call from time to time justifies.

Machine Printing.—Printing by machinery, is one of the latest achievements of art, having had its origin within the present century. It has produced a very great improvement in the expedition with which work is executed,

and is now extensively applied to the printing of newspapers and even of books. Various machines are already introduced into use, most of which perform the processes of inking the types, conveying the paper, and giving the impression. For distributing the ink on the types, elastic cylinders are employed, called inking *rollers*, made of a composition of glue and treacle, which combines the properties of smoothness, elasticity, and sufficient durability. These transmit the ink to the types by rolling over their surface. The impression is performed in most of the English machines, by large cylinders which revolve upon the types, having the sheet of paper confined to their surface by bands of tape. The types are arranged in some machines in the common flat form; in others, the characters are placed in a convex form upon the surface of cylinders. To produce the latter effect, Mr. Nicholson proposed to cast the body of the types with a tapering or wedge form, like the stones of an arch, but Mr. Cowper has produced the same object more expeditiously, by curving stereotype plates into the required shape. Messrs. Donkin and Bacon placed their types on the four sides of a revolving prism, while the ink was applied by a roller which rose and fell with the irregularities of the prism, and the sheet was wrapped on another prism so formed as to meet the surfaces of the first. A common printing press gives about two hundred and fifty impressions per hour, whereas of the 'Times,' a London newspaper, printed by Applegath and Cowper's machine, it is stated that four thousand per hour are printed on one side. The first *working* machine which printed by steam, was erected by Mr. Koenig, in 1814.

In most of the presses used in this country, the impressions are made by a flat surface or platten, instead of a cylinder, so that cleaner and better impressions are supposed to be obtained from it than from most other machines. Printing by machinery has now become common, and various modifications of the original machines are in use.

History.—The art of printing was first carried into successful operation, a little before the middle of the

fifteenth century. The honor of having given birth to the invention, is claimed by the cities of Haerlem, Mentz, and Strasburgh, in each of which the art was successfully practised at an early period. The best authors, however, agree in considering that the original inventor of printing was Laurentius, otherwise called Coster, of Haerlem, who made his first attempt in 1430, with separate wooden types. He died ten years after, having printed the 'Horarium,' the 'Speculum Belgicum,' and two different editions of Donatus, which were the first books. After his death, printing was carried on at Mentz, by John Gensfleisch, who had possessed himself of some of Laurentius's types, and who, like his master, printed in wood. This man, with the assistance of his brother, who is usually called Guttenberg, afterward invented cut metal types, with which was printed the earliest edition of the Bible. This edition appeared in 1450, having taken seven or eight years for its completion.

Guttenberg used none but wooden or cut metal types. The art received its consummation soon after, from Peter Schoeffer, who invented the mode of casting types in matrices. The celebrated Faustus, who has often been considered as the inventor of printing, was in partnership with the persons already mentioned, and furnished funds to defray the expenses of the enterprise, the processes being kept secret. The well-known tale of the practice of necromancy, by Faustus, was owing to his carrying a parcel of his Bibles to Paris, and offering them for sale as manuscripts. The French, finding so great a number of books resembling each other exactly, and more so than it was possible for any chirographer to have made them, concluded there was witchcraft in the case, and, by inditing Faustus as a conjuror, compelled him to disclose the secret in his own defence.

After the invention of printing with fusible types, it spread rapidly into many of the cities of Europe, and was practised at an early period at Tours, Rome, and Venice. It was first carried on in England by Caxton and Corsellis, about 1470, and the earliest press was established at Oxford.

It is remarkable that this important art, after becoming once established, underwent no essential improvement for a period of more than three hundred years. Having remained stationary for three centuries, it has received a fresh impulse within the last few years, by the invention of stereotyping, and of printing by machinery.

Although printing with movable types is exclusively a modern art, yet there are some steps in the discovery, which have claim to greater antiquity. The Chinese have printed with their characters for more than nine hundred years; but as the nature of this character requires that much should be expressed by a single figure, they are obliged to cut each character, with all its complications, in a block of wood, so that their method resembles a limited kind of stereotype printing.

Among the relics of ancient Rome, there have been found letters, cut in brass and raised above the surface, exactly like our printing types. Some of these contain the names of individuals, and, from their shape and appendages, were evidently used for the purpose of signature, the letters being small, smooth, and even, while the ground beneath them is unequal and rough, so that they must have been employed, not for impressions into soft substances, but for printing with colored liquids, on a surface like parchment or paper. Had the individuals, whose names were thus printed, been visited with the thought that by separating the letters, they might print the name of another, it is probable that the art would have been at once discovered, and that the dark ages might never have happened.

Works of Reference.—Astle, on the Origin and Progress of Writing, 4to. London, 1803;—Fry's Pantographia, 4to. London, 1799; —Townley's Illustrations of Biblical Literature, 1821;—Stower's Printers' Grammar, 8vo. London, 1808;—Thomas's History of Printing, 8vo. Worcester, U. S. 1810;—Meerman, *Origines Typographicæ Hagæ*, 1765;—Cowper, in Brande's Journal of Science, 1828;—Hansard's Typographia, large 8vo. 1825;—Adams's Typographia, Philadelphia, 12mo. 1837.

CHAPTER VIII.

ARTS OF DESIGNING AND PAINTING.

Divisions. *Perspective*, Field of Vision, Distance and Foreshortening, Definitions, Instrumental Perspective, Mechanical Perspective, Perspectographs, Projections, Isometrical Perspective. *Chiaro Oscuro* —Light and Shade, Association, Direction of Light, Reflected Light, Expression of Shape, Eyes of a Portrait, Shadows, Aerial Perspective. *Coloring.*—Colors, Shades, Tone, Harmony, Contrast. Remarks.

Designing is the art of delineating or drawing the appearance of natural objects, by lines on a plane surface. Painting may be considered as the same art, so extended as to include coloring, and whatever else is necessary to produce complete or finished resemblances. It is obvious, that if the art of painting was carried to perfection, these resemblances could not be told, at sight, from their originals; since we are supposed to discern objects by the medium of their pictures painted on the retina of the eye, and since a polished mirror gives us every appearance of reality, in the forms reflected from it, though they all proceed from the same plane.

Divisions.—To produce perfect representations of nature, three things must receive attention, and the study of these may be considered as constituting distinct departments in the art of painting. These are, 1. The *perspective*, by which the outlines of figures are placed on the picture in situations depending on their position in regard to the eye. 2. The *chiaro oscuro*, or light and shade, by which the prominence and depression of different parts of the piece are made to appear. 3. The *coloring*, by which the hues and tints of the painting are made conformable to those of the original.

PERSPECTIVE.

Perspective is the art of delineating the outlines of objects on any given surface, such as paper or canvass, just

as they would appear to the eye, if that surface were transparent, and the objects themselves were seen through it from a fixed position. It is the foundation of correctness in painting, and a strict attention to its rules, is indispensable to perfection in the art. The first attempts at drawing have, in all countries, consisted of diagrams and sketches, representing merely the plans, or profiles of objects, without regard to their perspective relations. But a continued attention to their actual appearance or images, combined with the application of a few geometrical and optical principles, has furnished the means of fixing the outlines of objects, in their true situation, on a perspective plane.

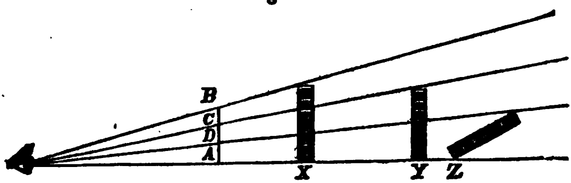
If we look through a window at a mass of buildings, or any external objects, and observe that part of the glass to which each object, line, or point, appears opposite, we find that their apparent situation is very different from their real. We find that horizontal lines sometimes appear oblique, or even perpendicular, that circles, in certain situations, look like ellipses, and squares like trapezoids or parallelograms. High objects are seen beneath low ones, and large bodies are exceeded, in apparent magnitude, by small ones. The foundation of all these appearances exists in the rectilinear motion of the rays of light passing from the object to the eye.

Field of Vision.—When the eye is fixed, the rays, entering it from the whole field of vision, constitute a cone, having its apex in the eye. The field presented to the eye, and occupying the base of the cone, cannot well subtend an angle of more than ninety degrees, and we cannot have a convenient and agreeable view of a field occupying more than sixty degrees. Even the most satisfactory views of objects are obtained at such distances as cause them to subtend an angle of thirty or forty degrees. *Panoramic* views subtend a larger angle than those which have been specified, and of course cannot be taken in by the eye at a single view. It becomes, therefore, necessary to take successive views with the eye, in different directions.

Distance and Foreshortening.—Of objects situated within the field of vision, those necessarily appear largest,

cæteris paribus, which are nearest to us, because they subtend a larger angle at the eye. Objects or surfaces situated obliquely in regard to the axis of the eye, are altered in apparent shape by the shortening of their oblique diameters. This is what is technically called *foreshortening*. If several objects, for example, of equal size, be placed at different distances, and in different positions,

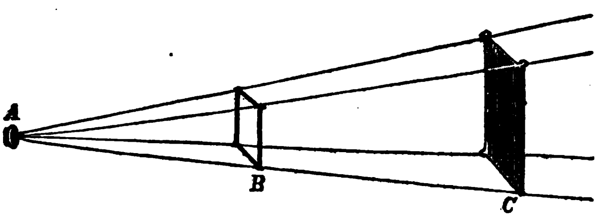
Fig. 10.



the one nearest the eye, as X, will subtend the largest angle, and its comparative length in the picture will be represented by the line AB. The object Y, being further off, subtends a smaller angle, and will be represented by the line AC. The object Z, being still further removed, and also foreshortened by its oblique position, will produce an image no longer than from A to D.

A simple instrument may be formed by any person, to represent the effect of distance and of foreshortening in perspective. Let four straight, stiff wires be connected

Fig. 11.



at one end, at A, by a string or socket, which will allow them to diverge. Let a thin, square board, or tin plate, be attached at the other end, at C, by loops at its four corners, through which the wires pass. Let a string of

elastic gum be placed around the wires at B, about half way between A and C. The elastic string will represent the picture, the board the object, and the wires the rays passing from the object to the eye at A. If now the board be moved upon the wires toward the eye, the elastic string will be extended, or the picture enlarged. The reverse will happen, if the board be carried away from the place of the eye. The board may also be turned into various oblique positions, and the elastic string will represent the figure produced by the foreshortening.

Definitions.—There are used in perspective a certain number of terms peculiar to the art, definitions of which are necessary to an intelligent use of them.

The *original object* is that which is made the subject of the picture.

Original planes or *lines* are the surfaces or lines of original objects.

The *point of view* is the situation of the eye.

The *point of sight* is the point in the perspective plane which is nearest to the eye. As far as the picture is concerned, these two points coincide, so that some authors have used them indiscriminately one for the other. The point of sight is also called the *centre* of the picture.

A *visual ray* is a line from the object to the eye. If the object is a point, there is but one visual ray; if it is a line, the visual rays form a triangle; if it is a square, they form a pyramid; if a circle, a cone, &c. The *principal visual ray* is that from the nearest point in the picture, or point of sight.

The *perspective plane* is the surface on which the picture is delineated; or, it is the transparent surface through which we suppose objects to be viewed.

The *directing plane* is a plane supposed to pass through the eye of the spectator, parallel to the perspective plane.

The *ground plane* is the earth, or the plane surface on which the spectator and objects are situated.

The *horizon*, or *horizontal plane*, is one parallel to the ground plane, and at the height of the spectator's eye.

The *horizontal line* is the intersection of the picture or perspective plane with the horizontal plane.

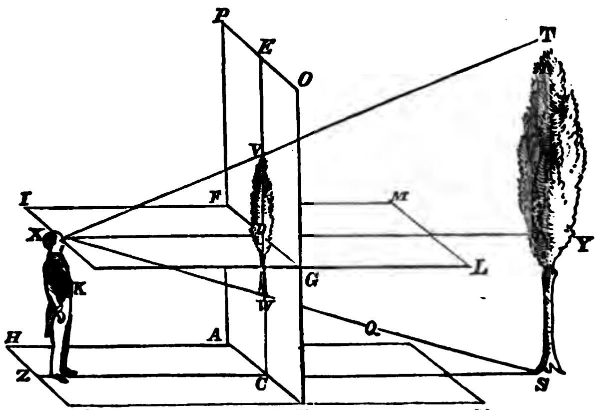
The *ground line* is the intersection of the perspective plane with the ground plane; or, it is the line on which the picture is supposed to stand.

The *perpendicular* is a line on the perspective plane, drawn through the point of sight, perpendicular to the ground line and horizontal line.

The *points of distance* are points on the perspective plane, set off from the point of sight, sometimes on the horizontal line, and sometimes on the perpendicular, at the same distance from the point of sight, that the eye is supposed to be at, from the perspective plane.

To render the foregoing definitions more obvious, a diagram is introduced, in which the several planes are

Fig. 12.



supposed to be *visible*, and themselves, or a part of each of them, seen in perspective. X is the eye of a spectator, or point of view. ST, the original object. XT, and XS, visual rays. XY, the principal visual ray. ABOP, the picture, or part of the perspective plane. VW, the image of the original object in the picture, or perspective plane. D, the point of sight, or centre of the picture. HNRQ, the ground plane. IKLM, the horizon or horizontal plane. AB, the ground line, or bottom

of the picture. FG, the horizontal line. CE, the perpendicular. E, a point of distance. Other points of distance would be at F and G, if equally distant from D with X or E.

The *vanishing point* of the image of a right line is the point in which a line parallel to it, passing through the eye, cuts the perspective plane. Lines which in the original are parallel, in the picture converge to the same vanishing point. Thus the parallel railings of a bridge, or the parallel rows of windows in a building, all appear to converge to the same point. All lines which are perpendicular to the perspective plane, have for their vanishing point the centre of the picture.

A great number of problems, founded on the principles of perspective, are to be found in works on that science, and constitute an interesting study. But in practice, artists find it convenient to resort to some more direct and compendious method of obtaining the perspective situation of objects, without the trouble of mensuration.

Instrumental Perspective.—The geometrical rules usually laid down for drawing in perspective, suppose a previous knowledge of the real distances, magnitudes, and relative positions of all the objects that are introduced into the picture. But, in many cases, a person may be so situated, that this knowledge cannot be obtained; and in many cases, likewise, the labor, which this method requires, is troublesome and discouraging. Dr. Priestley has described a method of drawing objects in true perspective, without moving from the place in which they are viewed. It consists simply in taking observations of the various points of an object, so as to determine their elevation above the horizon, and their declination from a perpendicular.

Mechanical Perspective.—To avoid wholly the delay and trouble of computation, artists frequently make use, in practice, of some mechanical method of perspective drawing, by which the outlines of objects can be obtained with expedition, and sufficient correctness. Thus the *camera obscura*, and *camera lucida*, cast upon paper a perspective image, which can be immediately traced. A

method of drawing by squares is likewise easily practised. For this purpose, the paper, or surface which is to receive the picture, is divided by pencil lines into a certain number of squares. A small frame, of corresponding size, is divided into a like number of squares by threads, or by lines drawn upon glass. This frame is placed perpendicularly between the eye and the object, and kept at a stationary distance from the eye, which is also fixed. The outlines and parts of objects which appear in particular squares of the frame, are transferred to corresponding ones on the paper, and in this way the principal points of the perspective view may be obtained.

Perspectographs.—Various instruments have been invented, under the name of *perspectographs*, to be used in obtaining the points and outlines of original objects. They commonly consist of a fixed part, perforated with a small hole in the point of view, and a movable part situated in the perspective plane, and capable of traversing any part of it. This movable part may consist of any minute substance, or, which is better, a movable point may be obtained by the intersection of two threads. Any points in the perspective plane may thus be found, and transferred to the picture, by bringing the part of the instrument which contains them, into contact with the paper.

A simple and very useful perspectograph may be made by erecting a pane of glass upon one end of a board, or short table, and an eye-piece with an aperture for the eye to look through at the other end.* The eye-piece is to be fixed at any convenient distance, and the object is to be viewed from it, through the pane of glass. The outlines, as they appear, are traced upon the glass with a stick of wax sharpened like a crayon, and they may be afterwards rendered very plain, and transferable, by sprinkling them with any black powder.

The geometrical and mechanical methods which have been described, will enable a person not previously conversant with the art, to obtain correct perspective representations of any object. But by long practice, in draw-

* No method fixes the eye so effectually, as to rest the teeth upon a solid or fixed body.

ing from nature, a certain tact is acquired by painters, which enables them, by the accuracy of the eye and judgement alone, to make correct views of objects, without the aid of any computation or mechanical process. Thus miniature painters produce the nicest resemblance of the human countenance, in any position, with no other guide, than the faculty obtained by experience, of estimating the exact shape and proportion, which each part of the original should bear upon the picture.

Projections.—The projections of a body, are the different modes by which it may be delineated on a plane surface. That which has already been described, is called the *scenographic* projection, and represents objects as they actually appear to the eye, at limited distances. The *orthographic* projection represents objects as they would appear to the eye at an infinite distance, the rays which proceed from them being parallel, instead of converging. The shadow, which a body casts in the rays of the sun, may be considered as an orthographic projection. In this projection, lines which are parallel in the original, are parallel in the picture, and do not converge to any vanishing point. Their comparative length, also, is not affected by difference of apparent distance. The orthographic projection is much used in delineating buildings, machinery, &c., because those parts of the drawing which are not foreshortened, maintain their true relative size, so that measures can be taken from them. The following figures represent the scenographic (Fig. 13) and orthographic (Fig. 14) projections of a cube. In addi-

Fig. 13.

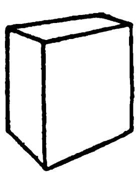
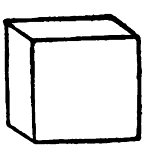


Fig. 14.

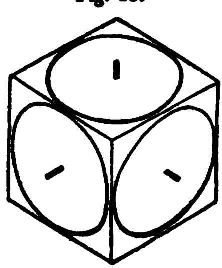


tion to these, the term *ichnographic* projection is sometimes used to express the horizontal delineation, or ground

plan, of an object. A *bird's eye* view is a scenographic or orthographic projection, taken from an elevated point in the air, from which the eye is supposed to look down upon the objects.

Isometrical Perspective.—This name has been introduced by Professor Farrish, to express a kind of drawing peculiarly convenient in delineations of machinery, and bodies of regular figure. It is a species of orthographic projection, in which three planes, at right angles with each other, appear similar and equal. An idea of it may be formed, by supposing a cube to be so placed, that one of its angles will appear in the centre, while its outline will be a true hexagon. In this projection, the sides of the cube appear equal, and all sections of the cube parallel to either side, will also be equal. All right angles are represented by angles of sixty degrees, or the supplement of sixty degrees. All circles parallel to either of the three planes, will be represented by similar ellipses. Figures not parallel to either of the planes, may be calculated by easy rules. It is therefore the easiest and most expressive kind of drawing for the wheelwork, axles, and regular frames of machinery; for philosophical instruments, and for many architectural designs.* The subjoined figure (Fig. 15) is an isometrical view of a cube,

Fig. 15.



with circles inscribed on its sides, and the axes of those circles projecting a short way.

* For the principles of isometrical drawing, see the Cambridge Philosophical Transactions; or Gregory's Mathematics for Practical Men, p. 179.

CHIARO OSCURO.

Next to correct perspective, the most important circumstance in painting, is the correct distribution of light and shade. To the skilful management of these, we are indebted for the strength and liveliness of pictures, and what is technically called their *relief*, or the elevation which certain parts appear to assume above the plane upon which the picture is made.

Light and Shade.—Light and shade, as they appear to us upon natural objects, are the consequences of the rectilinear motion of the rays cast upon them by luminous bodies. If an object be exposed to the rays of the sun, or of a single lamp or candle, those parts or surfaces which are presented directly to these rays, become strongly illuminated, and acquire a lighter cast, approaching to white. Those surfaces, which stand obliquely to the light, receive less of the rays, and of course have a deeper tinge. Those, lastly, which are averted from the light, and receive no rays but such as are reflected to them from other objects, acquire a very dark shade, approaching, when contrasted with the others, towards black.

The distribution of light and shade upon any object, is always proportionate and correspondent to its shape. An even or plane surface, exposed to the sun's rays, will be equally illuminated throughout, since whatever be its position, its parts will all make a similar angle with the rays. But uneven or irregular surfaces will be unequally illuminated, the prominent parts receiving most light, and the depressed portions most shade, an effect which will be increased, if the light falls obliquely or sideways. If the irregularities of surface be sharp and strong, the changes from light to shade will be sudden, and the contrast great. On the other hand, if they are smooth and rounded, the transition will be soft and gradual.

Association.—As bodies are never seen, except when they are illuminated, the manner in which light and shade are distributed upon them, forms by association a part of our ideas of their shape. Painters have learned to imitate this arrangement of light and shade, by varying the

quantity and intensity of their coloring substances, so as to produce in the mind the same associations of shape from a plane surface, as would arise from the falling of light on the original object itself. This art constitutes what is technically called the *chiaro oscuro*, from the Italian words signifying *clear* and *obscure*. Next to perspective, it is the most important part of painting, and there are many cases in which perspective alone would wholy fail to convey to us a correct idea of the form of objects, were it not assisted by appropriate insertion of lights and shades. Thus a circle, a sphere, and a cone, viewed vertically, may all have the same perspective outline; but their difference of figure becomes apparent, as soon as we consider their distribution of light and shade.

Direction of Light.—The most distinct perceptions of shape are produced when the light falls in one direction, *e. g.*, when it is received immediately from the sun, or from a single window or candle. The distinctness of an object is always impaired, when it is situated between cross lights, or when it is illuminated by a variety of windows or candles on different sides of the room. An object may even be so surrounded with lights, that it shall be impossible to discover its exact shape. Its outline indeed will be discernible, but the equal illumination on all sides, will exclude the existence of shadow, and of course we shall lose the power of appreciating the comparative distance of its parts from the eye. In most paintings, we find that the principal mass of light falls in one direction. An oblique or a sideway direction, is most common, though a front, and even a back light, is managed to produce very striking effects. Painters also exercise their skill with the introduction of cross lights, from different windows, or lamps; but the successful execution of a piece of this sort is more difficult, than with a single light.

Reflected Light.—Owing to the reflection which takes place from all terrestrial bodies, we find that objects, in most situations, have not only a principal or direct light, but also a secondary or reflected one. Hence the darkest part of globular and cylindrical bodies, is not that

which is most remote from the original light. This part receives from the reflection of objects beyond it, a faint illumination, so that the darkest part will be found between it and the part on which the light directly falls. See the sphere represented, Fig. 16.

Fig. 16.

Fig. 17.

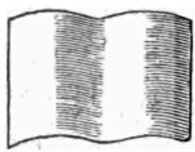
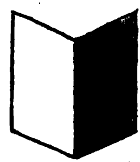


Fig. 18.



Sharp lights, or such as are intense and sudden, indicate polished surfaces, and are employed to represent them. Where they are accompanied by very deep shades, they express great elevation above the common surface. Faint lights, on the contrary, imply a dull surface, obscure illumination, or small elevation.

Expression of Shape.—Light and shade are not adequate, in all cases, to give us a certain indication of the forms of bodies. Surfaces which appear concave in one direction of the light, may appear convex, if the light is introduced from the opposite side. In contemplating an undulating object, like a curtain, or its picture upon paper hangings, we are often at a loss to distinguish the elevated, from the depressed portions; and by a little effort of the imagination, we can persuade ourselves that a particular part is at one time elevated, and at another, depressed. *Cameos* and *intaglios* may be mistaken for each other, and any of the figures (Figs. 16, 17, 18) may appear prominent or depressed, in the same part, by reversing the direction in which the light is supposed to strike upon them.

In cases of this sort, our final ideas of shape are derived, not only from the object itself, but from its relations with contiguous objects.

Eyes of a Portrait.—The influence which the associ-

ation of contiguous objects has upon our ideas, is strikingly exemplified in the eyes of a portrait. We estimate the direction of the eyes, not only from the position of the ball in regard to the eyelids, but also from the relative position of the remaining features of the face. Dr. Wollaston has shown, that the same eyes in a picture, which look at us, may be made to appear averted from us, if we apply new features to the lower half of the face. In the following figures, (19 and 20,) the eyes are the same, and their apparent direction depends on the other features of the face.

Fig. 19.

Fig. 20.

The reason, why the eyes of a portrait appear to follow us, in all parts of the room, is simply, that the relative position of the features cannot change, so that if the picture appears to look at us once, it must appear to look at us always. If we move to one side of a portrait, the change, which happens, is unlike that which would take place in a bust, or living face. The picture is merely foreshortened, so that we see a narrower image of a face, but it is still that of a face looking at us. And if the canvass be transparent, the same effect takes place from the back of the picture.

Shadows.—Shadows are cast in the direction opposite to that by which we suppose the light to enter, and their introduction in pictures, always heightens the effect. A painted object is relieved, or raised from the surface, by the expression of light and shade on itself. But the relief is greatly increased, if the shadow which it makes on the ground, or other surface, be also introduced. Shadows are commonly softened off at the edge, or terminate gradually. When, however, the light is strong, or the shadow very near to the object, its termination is more abrupt.

Aerial Perspective.—This name is given by painters, to the mode of producing the effect of distance, by a diminution in the distinctness and brightness of objects, according to their remoteness from the eye, and the condition of the medium through which they are seen. It is well known that distant objects appear indistinct, and of a grayish or blueish tinge, from the effect produced by the intervening atmosphere. Their indistinctness is increased, if the atmosphere is hazy. Their appearance is also modified by the degree of their illumination, and by the character of the light which falls on them. The painter, therefore, finds it necessary to consider the depth of atmosphere which is interposed between him and his object, the condition of this atmosphere, and the quantity and color of the light which falls on it, and on the object. A want of attention to these circumstances, gives rise to the defect called *hardness* in painting.

COLORING.

By the aid of perspective, and the *chiaro oscuro* alone, very good representations of objects may be obtained. All our common engravings, wood cuts, drawings in Indian ink, in black crayons, &c., derive their expressiveness from these only. But a still nearer approach to the appearance of Nature, is made by the employment of *colors* analogous to those which are found to exist in the objects represented.

Colors.—From the science of optics, we learn that the solar beam is divisible into seven primary colors, white being the mixture, and black the privation of all of them.

These colors are, violet, indigo, blue, green, yellow, orange, red.* Three of these are capable of producing all the rest, by their intermixture and degree, viz., blue, red, and yellow.

The color belonging to different natural objects, was supposed, by Newton, to be occasioned by a power which their surfaces possess, to reflect certain rays, while they absorb all the rest. This power is so infinitely diversified in Nature, that we find not only every kind of primary ray reflected, but likewise every posible tint, and intermediate grade, which can be produced by the admixture of two or more original colors. To represent these various hues, it is necessary that the painter should possess coloring substances analogous to them all, or capable of producing them all by mixture, and that he should apply them in such a manner, that the true color may remain distinct, independently of the lights and shades necessary to place the objects in relief.

Shades.—In a colored painting of an object which has any rotundity of form, there are usually, at least three tints, or degrees of color. These are the *light*, the *middle tint*, and the *shade*. Of these, the middle tint is the one which represents the true color of the object, and occupies an intermediate situation between the light and shade. Thus in the painting of a red fruit, for instance the cherry, the middle tint is vermilion, or some similar color, being that which the surface of the fruit would have, if it were perfectly flat. The part of the fruit nearest the light, has a very bright color, partaking of white, while the remote parts are shaded with lake or some darker red. In like manner, a yellow fruit, like the lemon, has not only the true color of the rind, but is lightened at the top with straw color or white, and shaded with brown toward the edges. It is necessary that the colors used

* Dr. Wollaston found the spectrum, formed in looking through a prism at a narrow line of light, to consist of four colors, red, green, blue, and violet, with a narrow stripe of yellow. The three simple colors, red, green, and violet, may produce yellow, by the admixture of red and green; crimson, by red and violet; blue, by green and violet; and white by the combination of all three.

for dark shading, should be in some degree correspondent with the middle tint, and not diametrically opposite to it. Thus, in single objects, yellow cannot be shaded with blue, nor red with green.

Tone.—Pictures differ from each other in the respective depth of color, which pervades the whole piece. The word *tone*, borrowed from the art of music, signifies, in painting, the peculiar cast, or governing hue, which a picture, or a color, possesses. Thus, if dark masses of color, with feeble lights, predominate, the piece has a deep or low tone; while, if the reverse exists, a bright or light tone is produced. It is essential to harmony that a picture should have the same tone throughout, or that its lights and shades should correspond in their intensity to the tone which governs the whole.

Harmony.—When different objects are grouped together in the same view, each one possesses two kinds of color, the *original* color, and the *adventitious*. The original color, often called among painters the *local* color, is that which belongs to the object itself, independent of situation. The adventitious color, is that which is reflected upon it from neighboring objects, and which, of course, depends upon situation. For example, the color of the human face is that which we call flesh color, and, if painted alone, may be represented by the shades of that color. If, however, it is surrounded by a purple drapery, it receives a purplish tinge, and requires to be so represented. In like manner, a yellow dress communicates to it a yellowish cast, &c. An attention to this adventitious coloring, combined with a uniformity of tone, constitutes the basis of what is technically called *harmony* in painting. Harmony requires that strong and glaring colors should never be forcibly contrasted with each other, but that each object should partake at its edges of a certain portion of the color which predominates in objects near to it. This rule not only produces effects most grateful to the eye, but an observance of it gives, in fact, the only true representation of Nature.

Contrast.—Colors are divided, by painters, into the *warm* and the *cold*. Warm colors are those in which

red and yellow predominate. Cold colors are blue, gray, and others allied to them. Neutral colors are intermediate tints, or mixtures. Of the various pigments or coloring substances, which painters employ, none have the genuine brilliancy of the prismatic rays ; and all fall short of the hues produced by Nature in living objects. The petal of a flower, the feather of a bird, and the wing of an insect, are tinged with a richness and splendor, which no factitious colors can equal. Painters can only approach, when necessary, towards the brightness of natural colors, by availing themselves of the effect of contrast, and by heightening one color by the introduction of others, which prepare the eye for its more perfect and favorable reception.

Remarks.—The power of giving true representations of objects, is derived, originally, from an attentive study of the colors and appearance which they actually exhibit in Nature ; afterwards from a comparison of the success of different artists, and an attention to the means they have employed. What belongs to the philosophical part of painting, can hardly be said to extend beyond the correct imitation of Nature. But the inventive part, the design and composition of great pieces, such as have not necessarily any originals in Nature, requires not only philosophic accuracy, and practical skill, but also demands original genius, strength and fertility of imagination, and a strong perception of sublimity and beauty, whether natural or moral. To paint a portrait or landscape from Nature, requires no more than a faculty of correct imitation. But to express on the canvass a scene of history or of fiction, to create forms of ideal beauty exceeding the realities of life, and to express, by attitudes and lineaments, passions, which tell the events they accompany,—this excellence is attained by few ; it is not to be taught by any rules of art, but, like poetry and eloquence, it is within the reach of those only, whom a strong and exclusive interest in the pursuit has qualified to feel deeply, and to express powerfully.

Note.—For the modes of painting in water, oil, fresco, &c., also for coloring substances, see Chapter VI.

WORKS OF REFERENCE.—MALTON'S Treatise on Perspective, fol. 1779;—PRIESTLEY'S Introduction to Perspective, 8vo. 1770; —WOOD'S Lectures on Perspective, with an Apparatus, 1809;— BLUNT'S Essay on Mechanical Drawing, 4to. 1811;—SOPWITH'S Treatise on Isometrical Drawing, 8vo. 1835;—LUCAS'S Progressive Drawing Book, Baltimore, 1827;—BURNET, on Light and Shade, 4to. 1827;—BURNET, on Coloring, 4to. 1827;—VALLEE, *Traité de la Science du Dessin*, 4to. Paris, 1821;—MILLIN, *Dictionnaire de Beaux Arts*, 8 tom. 8vo. 1806;—ELMES'S Dictionary of Fine Arts, 8vo. 1806;—Works of Sir J. REYNOLDS,—OPIE,—FUSELI,— BARRY,—WEST,—DE PILES, &c. &c.

CHAPTER IX.

ARTS OF ENGRAVING AND LITHOGRAPHY.

ENGRAVING.—Origin, Materials, Instruments, Styles, Line Engraving, Medal Ruling, Stippling, Etching, Mezzotinto, Aqua Tinta, Medallic Engraving, Copperplate Printing, Colored Engravings, Steel Engraving, Wood Engraving. LITHOGRAPHY.—Principles, Origin, Lithographic Stones, Preparation, Lithographic Ink and Chalk, Mode of Drawing, Etching the Stone, Printing, Printing Ink. Remarks.

THE arts of engraving and lithography bear the same relation to drawing, that the art of printing does to that of writing; the first being intended for the expression of original designs, the latter for the multiplication of copies of the design, when made.

ENGRAVING.

Origin.—The origin of copperplate engraving appears to have been in the fifteenth century, previously to which time it was probably unknown. The first inventors of engraving, were the *goldsmiths*, who, from the habit of marking ciphers and little devices on their wares, acquired a dexterity and despatch in the use of the graving tool, and at the same time, a power of producing subjects of such neatness and delicacy, that a desire was naturally excited in them, to preserve and increase the products of the art, by transferring them to paper. This object

was effected by the use of a suitable pigment, and the aid of the rolling press.

Materials.—Common engraving differs from printing, in having its subjects or devices cut into, or below, the surface of a metallic plate, instead of being elevated or raised above it, as in types, and wood cuts. For the purpose of engraving, a variety of metals have been employed, and various combinations or alloys. *Copper* has, however, been selected by common consent, as uniting the greatest number of desirable qualities; having sufficient softness to permit it to be cut when cold, and sufficient hardness and tenacity, to resist the action of the press, and the wearing of continued friction. A plate of the best copper is selected, about one fourth of an inch thick, having one side finely polished, and its edges rounded, to prevent it from cutting the paper. The engraver works opposite to a window, having a screen interposed to soften the light, and the plate placed on an oblique table in the most convenient position for seeing.

Instruments.—The instruments employed in the practice of the art, are the following. 1. The *graver*. This is a small steel bar, of a prismatic form, having one end attached to an oblique handle, and the other ground off obliquely, so as to produce a sharp point at one angle. In working, this instrument is held in the palm of the hand, and pushed forward, so as to cut out a portion of the copper. 2. The *dry point*. This is a strong, bluntish needle, fixed in a handle, and intended for drawing the finer lines. It is held in the fingers, in the same way as a pen or pencil. 3. The *scraper*, a triangular instrument, with concave sides, and sharp edges, intended for removing or scraping off portions, which are accidentally raised above the surface. 4. The *burnisher*. This is merely a blunt, smooth tool, for rubbing out blemishes, and smoothing the surface of the copper. Various kinds of varnish, rosin, wax, charcoal, and mineral acids, are also employed in different parts of the operation, according to the subject and the style of engraving which is adopted.

Styles.—The principal varieties or styles of engraving

on copper, are the following. 1. Line engraving. 2. Stippling. 3. Etching. 4. Mezzo tinto. 5. Aqua tinta. Lithography, and some other modes of multiplying designs, are imitations and substitutes, rather than species of engraving.*

Line Engraving.—Line engraving, called by the French, *Gravure en taille douce*, is one of the most common species of engraving; and though less elaborate than the second mode, has produced most of the finest and boldest specimens of the art. In this species, the surface and figures, the lights and shades, are produced by the multiplication of minute lines, cut in by the graver and dry point, approaching each other so nearly, that the inequality produced by the admixture of black and white does not offend the eye, nor interrupt the harmony of the piece. The effect and beauty of line engravings, depends much upon the smoothness of the lines, their gradual swell and decrease, and their evenness or parallel situation.

For engraving in this manner, the artist transfers the outlines of his original drawing, by tracing them with black lead, on an oiled paper,† and afterwards passing this paper through the press in contact with the copper-plate, which is previously covered with a thin coating of wax. A sufficient quantity of the lead adheres to the copper, to enable him to engrave the outlines with great accuracy. The graver is then held in the palm of the hand, and pushed forward, with a strong but steady and regular motion, until a line is completed. The graver, by its operation, removes a thread of copper from the line, and at the same time raises the surface on each side of it, forming what is called a *burr*. This burr is subsequently removed by the process of scraping and burnish-

* Musical characters are sometimes executed in a mode different from all these, by making impressions with a punch upon pewter, or some other soft metal.

† Paper rendered transparent with spermaceti, is useful in tracing figures with a lead pencil. If paper be varnished with a mixture of Canada balsam and oil of turpentine, very distinct lines may be traced on it with the dry point only, and these may be again transferred, by varnishing the copper, and tracing them upon it, through the paper. This method is now much employed by engravers.

ing. After the outlines are finished, the dark surfaces are introduced by means of close parallel lines cut in, in the same manner as before. Gradations of light and shade are produced by the gradual and simultaneous tapering of all the lines which constitute the dark portions; and the softness and regularity with which this is accomplished, greatly affects the beauty of the piece. Very dark shades are produced by lines crossing each other, either in squares or lozenges, which are varied according to the nature of the subject. Very light shades, on the contrary, are left untouched, or covered with broken lines. Lines which swell or taper, are first cut of a uniform size, and afterwards deepened by a second or third stroke of the graver. Mistakes or blemishes, are erased from the plate, either by burnishing with the proper instrument, or by rubbing with charcoal.

Stippling.—The second mode of engraving, is that called *stippling*, or engraving in dots. This resembles the last mentioned method in its processes, except that instead of lines, it is finished by minute points or excavations in the copper. These punctures, when made with the dry point, are circular; when made with the graver, they are rhomboidal or triangular. The variations and progressive magnitude of these dots, give the whole effect to stippled engraving. This style of work, is always more slow, laborious, and of course more expensive, than engraving in lines. It has, however, some advantages in the softness and delicacy of its lights and shades, and approaches nearer to the effect of painting, than the preceding method. A more expeditious way of multiplying the dots, has been contrived in the instrument called a roulette, a toothed wheel, fixed to a handle, which, by being rolled forcibly along the copper, produces a row of indentations. This method, however, is less manageable than the other, and generally produces a stiff effect.

Etching.—Etching is the third mode of engraving, and is performed by chemical corrosion. It is apparently the easiest mode of engraving, requiring least practice in the operator. In fact, any person who can draw, may etch

coarse designs tolerably well, after having acquainted himself with the theory only. Hence we find that engineers, naturalists, surgeons, &c., sometimes etch their own plates, especially of light subjects.

A plate for etching, is prepared in the same manner as for common engraving. It is then covered throughout its whole surface, with a very thin coating of varnish made of wax, mastic, and asphaltum; sometimes of rosin and animal oil, or of linseed oil inspissated by boiling. This varnish is blackened by the smoke of a lamp, in order that the operator may see the progress and state of his work. The instrument used in etching, is a needle, resembling the dry point, but of different sizes, according to the nature of the work. The plate being prepared, the operator, supporting his hand on a ruler, begins to make his drawing with the needle in the coat of varnish, taking care to penetrate always to the copper. In the use of the needle, those lines which require to be deepest, must have the greatest force bestowed on them, but it is not possible to produce so perfect an effect in this way, as by incisions of the graver. After the design is completed, the operator proceeds to the second part of the process, the corrosion, or, as it is technically called, *biting in.* For this purpose, the plate is surrounded with a wall of soft wax, to prevent the escape of fluid from its surface. A quantity of diluted nitric acid is then poured upon it, and suffered to remain for some time. A chemical action immediately takes place in all the lines or points where the copper is denuded by the strokes of the needle, while the rest of the surface is defended by the varnish. In the mean time, the operator brushes the surface frequently, with a feather, to clear away the bubbles and saturated portions of the metal. After the first biting is continued for a sufficient length of time in the judgement of the operator, the acid is poured off, and the plate examined. The light shades, if found sufficiently deep, are then covered with varnish, or, as it is technically called, *stopped out*, to protect them from further action of the acid. The biting is then continued for the second shades, which are next stopped out, and these

processes are alternately repeated till the piece is finished. The plate is then freed from varnish, by melting and wiping it off, and cleansed by washing with oil of turpentine. It must, in this state, be carefully examined or proved, and any deficiencies in the lines, owing to the accidental presence of varnish, must be finished with the graver. The plate is then ready for the press.

The productions of the etching needle, can never have the smoothness and beauty of *mechanical* engravings. Notwithstanding all the care which may be taken, the lines will have an irregularity and roughness, owing to the unequal action of the acid. There are, nevertheless, subjects, to which this very irregularity renders etched work peculiarly suited. Those objects which in nature are rough and coarse, are well represented by this species of engraving. The trunks of trees, broken ground, rocks, walls, cottages, &c., especially when executed on a large scale, receive a more natural aspect from the rough effect of etching than they could do without great labor from the softer touches of the graver. In landscape engraving, we commonly find a mixture of methods, the coarser parts being etched, while objects of more delicacy are cut with the graver. Letters and written characters, are mostly cut, and but seldom etched.

Mezzo Tinto.—Engraving in *mezzo tinto*, or *mezzotint*, is the fourth species. This method is the reverse of all those hitherto mentioned, and consists in bringing up lights from a dark ground. The mezzo tinto was invented by Prince Rupert, in 1649. Since his time, it has been greatly improved, and though not calculated for general use, it has been applied to various subjects with great success. For engraving in mezzo tinto, the whole surface of the copperplate is first roughened, or covered with minute prominences and excavations, too small to be obvious to the naked eye; so that if a impression be taken from it in this state, it has a uniform velvety black appearance. This roughness is produced mechanically, by the operations of a small toothed instrument, denominated a *cradle*. This instrument, by continual turns and impressions, which occupy a great length of time, gradually breaks up and

produces a uniform roughness on the whole surface of the plate. That the ground, as it is called, may be of the requisite fineness, the operation must be repeated a considerable number of times, the position of the plate in regard to the instrument, being varied each time. This is the most tedious part of the labor. When the plate is prepared, the rest of the process, to a skilful engraver, is easy, when compared with cutting or stippling. It consists in pressing down or rubbing out the roughness of the plate, by means of the burnisher and scraper, to the extent of the intended figure, obliterating the ground for lights, and leaving it for shades. Where a strong light is required, the whole ground is erased. For a medium light, it is moderately burnished, or partially erased. For the deepest shades, the ground is left entire. Care is taken to preserve the insensible gradations of light and shade upon which the effect and harmony of the piece essentially depend.

Engraving in mezzo tinto, approaches more nearly to the effect of oil paintings than any other species. It is well calculated for the representation of obscure pieces, such as night scenes, &c. Some individuals have applied it, with good success, to the engraving of portraits. The principal objection to the method is, that the plates wear out speedily under the press, and of course yield a comparatively small number of impressions.

Aqua Tinta.—Engraving in *aqua tinta,* is the only remaining mode. This is done by a process partly chemical, and partly mechanical. It consists in producing chemically, a rough ground, covering the surface of the figure to be engraved, and afterwards introducing the lights and shades by mechanical means. It may, however, be executed by a process wholly chemical. For engraving in aqua tint, the surface of the copper, after having the outline engraved or etched in the usual way, is covered throughout with minute particles of resin, invisible to the naked eye, detached from each other, and adhering to the surface of the metal. This process, called *laying the ground*, is effected in different ways. One method is, to enclose a quantity of finely-powdered rosin or mastic, in a flannel or linen bag. This is held at a certain height above

the plate, and beat with a stick. A cloud of fine dust issues from the bag, and settles upon the surface of the plate, with the same uniformity as the dust of the atmosphere settles upon furniture in dry weather. This dust is fixed to the surface, by heating the plate till the resin melts. The ground is thus laid. A second mode is, to cover the plate with a coat of very thin spirit varnish, prepared for the purpose. This varnish is so fluid, or contains so little resin, that when it dries by the evaporation of the spirit, the whole surface breaks up, or cracks into an infinite number of particles, all adhering to the plate. After the ground is completed, the vacant parts of the plate, or those not intended to be occupied by the figure, are *stopped out*; *i. e.*, covered by a thick varnish, impenetrable to acid. The plate is now surrounded by a wall of wax, as for etching, and diluted nitric acid is poured on. A chemical action immediately commences in all the interstices between the resinous particles; and the face of the plate, for the desired extent, is converted into a porous surface, made up of little prominences and excavations. The lighter shades are stopped out at an early stage of the process, and the corrosion continued for the dark ones. After the plate is judged to be sufficiently bitten in, it is cleaned, and proved by an impression. If the ground is good, *i. e.*, not too faint, too coarse, or too uneven, the work is then finished by burnishing the shadings to give them greater softness, and, if necessary, by cutting deep lines or dots in the darkest parts.

Engraving in aqua tinta has the greatest resemblance to paintings in water colors, or in Indian ink. When well executed, the white points, which diversify the surface, are nearly invisible to the naked eye, so that a uniform surface is presented. The art was first invented by a Frenchman, by the name of Leprince, who for some time kept his art a secret, and sold his impressions for original drawings. It is a mode of engraving well adapted to light subjects, sketches, landscapes, &c., and for subjects of which only a few copies or impressions are wanted. Owing to the fineness of the ground, the plates wear out rapidly, and seldom yield, when of the ordinary strength, more than six hundred impressions.

Aqua tinta is the most precarious kind of engraving, and requires much experience and attention on the part of the artist, to succeed well. If the ground is laid too thick, or too thin, the result is imperfect. If the corrosion by the acid is not continued long enough, the ground is too faint; if continued too long, the acid acts laterally, and destroys the whole surface. It is often necessary to repeat the whole process, and to go through the operations of laying the ground, stopping out, and biting, a number of successive times, before a ground is obtained of sufficient strength and regularity to answer for the press.

Medallic Engraving. This beautiful art is supposed to have been invented in Philadelphia, by Mr. A. Spencer, prior to 1817. The object of this kind of engraving is, to give accurate representations of medals, coins, and bas-reliefs of a small size; and is effected by applying a machine to the surface of the medal, which will trace a line on the copper, corresponding exactly to the outline of the figure on the medal. Those who are familiar with a pantograph will be able to form an idea of this machine. It is so contrived, that, as it slides over the surface of the coin, every elevation or depression, which produces a perpendicular motion in the machine, causes at the same time a horizontal movement at the other extremity, which traces the line on the copper. Every time the machine passes over the coin, a single line is traced on the copper; and there is a delicately-contrived screw, by which the machine may be pushed forward after each line is drawn, so as to make the next line as near to it as the operator chooses. The effect is, to give an exact copy of the medal; and the drawing appears so salient, that we can hardly convince ourselves, at first, that we are looking upon a flat surface.

Copperplate Printing.—Copperplate printing is performed by means of a rolling press, in which the plate and paper are strongly compressed together between a cylinder of wood and a sliding platform. The ink employed for copperplates, is made of a carbonaceous substance, called Frankfort black, and linseed oil, inspissated by boiling. Oil must be used, instead of water, that the

ink may not dry during the process; it is boiled till it becomes thick and viscid, that it may not spread upon the paper. Previously to the operation, the paper is wet, as for printing with types. The printer, having warmed his plate over a bed of coals, proceeds to cover its surface with ink by an instrument resembling a printer's roller. When the cavities of the engraving are thoroughly charged with ink, the smooth surface of the plate is wiped as clean from ink as possible. The latter part of the wiping is always performed by the palm of the hand, aided by a little dry powder, commonly whiting. The ink remains only in the crevices of the engraving, into which the hand does not penetrate in wiping the surface. The plate is next laid on the sliding plank, with its face upward, and the paper laid upon it. An elastic substance, commonly folds of woollen cloth, is placed above and below. A turn of the cylinder carries the plate under a very strong pressure, by which portions of the paper are forced down into all the cavities of the engraving. The ink, or a part of it, leaves the copper and adheres to the paper, giving an exact representation of the whole engraving.

Colored Engravings.—Colored engravings are variously executed. The most common are printed in black outline, and afterward painted separately in water colors. Sometimes a surface is produced by aqua tinta, or stippling, and different colors applied in printing to different parts, care being taken to wipe off the colors in opposite directions, that they may not interfere with each other. But the most perfect as well as elaborate productions, are those which are first printed in colors and afterwards painted by hand.

Steel Engraving.—The process of steel engraving, introduced by Mr. Perkins, depends on the property, which steel has, of being softened, by losing a part of its carbon; and afterwards of being hardened, by regaining it. If a steel plate, prepared for engraving, be enclosed in a box with iron filings, and exposed to a white heat for some hours, the surface loses a portion of carbon, and becomes sufficiently softened to be cut with the graver.

If then the plate, after being engraved, is reexposed to heat in a box with animal charcoal, the surface becomes again carbonated, and an engraved steel plate is thus obtained.

The great advantage of steel plates consists in their hardness, by which they last for an indefinite time, and yield an almost unlimited number of impressions; whereas a copperplate wears out after two or three thousand impressions, and even much sooner, if the engraving be fine. An engraving on a steel plate, may be transferred in relief to a softened steel cylinder, by pressure; and this cylinder, after being hardened, may again transfer the design, by rolling it upon a fresh steel plate; and thus the design may be multiplied at pleasure.

Steel engraving is of use, where a great number of impressions are called for; as it saves the expense of engraving the plate anew, and furnishes copies more exactly resembling each other, than can be obtained by any other mode. Of course, it affords the greatest security against counterfeiting.

Etching on steel plates, is practised with various chemical agents, one of which consists of a mixture of six parts of acetic acid, with one of nitric acid. Another menstruum is made by dissolving an ounce of corrosive sublimate, and a quarter of an ounce of alum, in half a pint of water.

Wood Engraving.—Engravings in wood are differently executed from those already described, the subjects being cut in relief; so that they require to be printed in the same manner as common types, and not with the rolling press. The material used is boxwood, which unites the properties of hardness, fineness, and density. It is cut across the grain into pieces of the height of common types, in order that the engraving may be made upon the end of the grain, for the strength and durability. The surface being planed very smooth, the design is drawn upon it with a black-lead pencil. The lines of this design are left untouched, but the whole of the intermediate spaces between the lines are cut away with a common graver, or chisel. Wood engravings have the ad-

vantage that the blocks may be inserted in a page with common types, and printed without separate expense. They are exceedingly durable, and may, if desired, be multiplied by the process of stereotyping.

LITHOGRAPHY.

Lithography is the art of taking impressions from drawings or writings made on *stone*, without engraving.

Principles.—This art is founded on the property which stone possesses, of imbibing fluids by capillary attraction, and on the chemical repulsion which oil and water have for each other. A drawing is first made on stone, with an ink, or crayon, of an oily composition, and the surface is washed over with water, which sinks into all the parts of the stone, not defended by the drawing. A cylindrical roller, charged with printing ink, is then passed over the surface of the stone. The drawing receives the ink, which is oily, while the other parts of the stone repel it, being defended by the water. The process, therefore, depends entirely on chemical principles, and is thus distinct from letter-press or copperplate printing, which are mechanical. On this account, it has, in Germany, been called *chemical printing*.

Origin.—The invention of lithography is generally ascribed to Alois Senefelder, the son of a performer at the Theatre of Munich, who received his education at the University of Ingoldstadt. Having become an author, and being too poor to publish his works, he tried many plans with copperplates, and compositions, and accidentally with stone, as substitutes for letter-press, in order to be his own printer. His first essays to print for publication, were some pieces of music, executed in 1796, after which he attempted various drawings and writings. The first productions of the art were rude and of little promise. Its progress, however, has been so rapid, that it now gives employment to a vast number of artists, and works are produced which rival the finest engravings, and even surpass them in the expression of certain subjects.

Lithographic Stones.—As calcareous stones will all

imbibe oil and water, and receive the action of acids, they are all capable of being used for lithography. Those, however, are best adapted to the purpose, which are compact, of a fine and equal grain, and free from veins, or imbedded fossils or crystals. A conchoidal fracture is considered a good characteristic.

The quarries of Solenhofen near Pappenheim, in Bavaria, furnished the first plates, and none have as yet been found to equal them in quality. They are of a uniform, pale yellowish or bluish white color, and the fracture is perfectly conchoidal. Generally, the hardest are considered best, provided they are uniform in texture. Such are necessary for fine chalk drawings, while softer ones answer for ink, or for coarser drawings in chalk.

In France, stones have been found near Chateauroux, of a similar color to those of Solenhofen, and even harder, and of a finer grain, but they are full of spots of a softer nature, so that it is difficult to procure pieces of the necessary size. In England, a stone has been used for lithography, which is found at Corston, near Bath. It is one of the white *lias* beds, but not so fine in grain, nor so close in texture as the German stone, and therefore inferior. In the extensive limestone tracts of the United States, there is little doubt that future observation will bring to light stones of a suitable character for lithography.

To bear the pressure used in taking impressions, a stone twelve inches square, should be an inch or two thick; and the thickness must increase with the size of the stone.

Preparation.—The stones are first ground to a level surface, by rubbing two of them face to face with sand and water. To prepare them for *ink drawings*, they are next polished with pumice-stone. But when they are intended for *chalk drawings*, they are merely ground with fine sand, which has been passed through a sieve, and which produces a smooth and uniform surface, which is grained and not polished, this surface being best adapted for holding the chalk.

Lithographic Ink and Chalk.—For these materials,

the union of several qualities is required, to obtain which, it is necessary to combine several substances together.

For lithographic *ink*, a great many different receipts have been given, one of the most approved of which is, a composition made of equal parts of tallow, wax, shell lac, and common soap, with about one twentieth part of the whole, of lampblack. These materials are mixed in an iron vessel. The wax and tallow are first put in, and heated till they take fire, after which, the other ingredients are successively added. The burning is allowed to continue until the composition is reduced about one third.

Lithographic *chalk* should have the qualities of a good drawing crayon; it should be even in texture, and carry a good point. The following proportions are among the best. Soap, 1½ oz.; tallow, 2 oz.; wax, 1½ oz.; shell lac, 1 oz.; lampblack, ¼ oz. The manipulation is similar to that for the ink.

Mode of Drawing.—With these materials, the artist proceeds to work on the prepared stone, after wiping it with a dry cloth. The ink being rubbed with warm water, like Indian ink, is used on the *polished* stone, and a gradation of tints can be obtained, only by varying the thickness of the lines, and the distance at which they are placed apart. It is necessary to mix the ink to such a consistency, that, while it works freely, it shall yet be strong enough to stand perfect, through the process of printing. A consistency, a little greater than that of writing ink, is sufficient for this purpose. The instruments used for drawing with ink, are steel pens, and fine camel's hair pencils.

The *chalk* will not hold upon the *polished* stone. But the *grained* stone, prepared for chalk, may be drawn upon with the chalk crayon, as easily as paper. The subject may be traced on the stone, with lead pencil or red chalk, but it should be done so lightly, as not to fill up any of the grain of the stone. In drawing, the degree of pressure of the hand will vary the strength of the tint, and it is desirable to give the requisite strength at once, as the surface of the stone is a little altered, by receiving the chalk, and hence it does not take any additional lines with

the same equality. Practice is necessary to give a command of the material, as it does not work quite like the common crayon, there being great difficulty in keeping a good point. There is also difficulty in obtaining the finer tints perfect in the impression; and for the light tints, the chalk must be used in a reed, as the metal port-crayon is too heavy to draw them, even without any pressure from the hand. A scraper is used to correct errors, and also to produce lights.

It is necessary to observe that the grain with which the stone is prepared, should vary with the fineness of the drawing. Several pieces of chalk should be prepared to use in succession, as the warmth of the hand softens it. It is useful to cut the chalk to the form of a wedge, rather than a point, as it is less likely to bend, in that form. Small portions of the point will break off during the drawing; these must be carefully removed with a small brush.

Etching the Stone.—After the drawing is finished on the stone, as before described, it is sent to the lithographic printer, who proceeds to *etch* the drawing, as it is called. The stone is placed obliquely on one edge over a trough, and very dilute nitric or sulphuric acid is poured over it. The degree of strength, which is little more than one *per cent.* of acid, should be such as to produce a very slight effervescence. The object of this slight etching appears to be to produce a chemical, rather than a mechanical change of surface, and it is by some considered superfluous, except to discharge the alkali of the soap.

The stone is now carefully washed, by pouring clean rain-water over it, and afterwards gum-water; and when not too wet, the roller, charged with printing ink, is rolled over it in both directions, till the drawing takes the ink. It is then well covered with a solution of gum-arabic in water, of about the consistency of oil. This is allowed to dry, and preserves the drawing from any alteration, as the lines cannot spread, in consequence of the pores of the stone being filled with gum.

Printing.—When the stone is ready for the press, the printing ink is applied to it, by means of an elastic roller, covered with leather. In the lithographic press,

the paper is first brought in contact with the stone, and protected by a tight cover of strong leather. The whole is then passed under the edge of a blunt wooden scraper, which is powerfully pressed down by a double lever, and thus every part of the paper is successively brought into forcible contact with the stone, and an accurate impression received of the drawing. The ink is then reapplied to the stone, and the process repeated for each impression.

Printing Ink.—This is composed, as other printing inks are, of oil-varnish, and fine lampblack. To prepare the varnish, a vessel is about half filled with pure linseed oil, and heated till it takes fire from the flame of a piece of burning paper. It should then be allowed to burn, till it is reduced to the degree of density required.

Remarks.—The great distinction of lithography from engraving is, that it gives a facsimile of the original drawing, which retains the freedom and touch of the artist's own hand, while, on the contrary, an engraving must be a copy. This character in a lithographic print, arises from the facility with which the drawing is produced, as the process is exactly that which the artist would follow, in making a common drawing. A further advantage, derived from the same cause, is, that the drawing being made at once on the stone, the whole expense of engraving is saved.

The more finished drawings in ink, however, have not the same advantages; for the gradations can only be obtained by the variations in the breadth and the distance of the lines, which is the same principle as that on which the engraver works; and hence the labor is more nearly equal in the two methods. The number of impressions, which can be taken from a lithographic chalk drawing, will vary according to the fineness of the tints. A fine drawing, will give four hundred, or five hundred; a strong one, one thousand, or one thousand five hundred. Ink drawings, and writings, give considerably more than copperplates. The finest will yield six thousand, or eight thousand; and strong lines, and writings, many more. Upwards of eighty thousand impressions have been taken at Munich, from one writing, of a form for regimental returns.

A method has been introduced, by which copies of valuable engravings may be multiplied indefinitely. An impression on paper is taken, in the usual manner, from the copperplate, and immediately laid with its surface upon water. When sufficiently wet, it is carefully applied to the surface of a stone, prepared in the usual manner, and pressed down upon it by the application of a roller, till the ink leaves the paper, and adheres to the stone. It is then printed in the common way. Autographic writings may be transferred from paper to stone, and printed in a manner nearly similar.

A common printed page, being originally made with an oily ink, is capable of being transferred to stone, by softening it with a chemical solvent and passing it through the press in contact with the stone. Copies can thus be indefinitely multiplied.

WORKS OF REFERENCE.—LANDSEER'S Lectures on Engraving, 8vo. London, 1807 ;—MEADOWS'S Lectures on Engraving, London, 1811 ;—PARTINGTON'S Mechanic's Gallery, 8vo. 1825 ;—REES'S Cyclopædia, under the various heads ;—HULMANDEL'S Treatise on Lithography, 8vo. 1817 ;—SENEFELDER'S Complete Course of Lithography, 4to. ;—London Journal of Arts, *passim* ;—DE LASTEYRIE, *Journal de Connaisances usuelles*, translated, Franklin Journal, vol. iv. ;—North American Review, 1834.

CHAPTER X.

OF SCULPTURE, MODELLING, AND CASTING.

Subjects, Modelling, Casting in Plaster, Bronze Casting, Practice of Sculpture, Materials, Objects of Sculpture, Gem Engraving, Cameos, Intaglios, Mosaic, Scagliola.

Subjects.—Sculpture, in its most general sense, is the art of producing resemblances of visible forms, out of solid materials. The required shapes are produced by *carving*, when the material is solid and brittle ; and to this sense the term sculpture is sometimes limited. They are also formed by *modelling*, when the material is soft ;

and by *casting*, when it is liquid or fusible. The productions of this art are known under various denominations, according to their character and subject. Of these, the most important are *statues*, which are entire resemblances of living objects. *Busts* consist of the upper portions of statues. *Bas-reliefs*, in the common acceptation of the term, are partial sculptures, or lateral views of figures, raised on a plane surface. Their different degrees of prominence are distinguished by the Italians, under different names. These are, *alto relievo*, or high relief, when the figures are nearly complete, or appear to issue from the back-ground; *mezzo relievo*, or middle relief, in which they are half raised from the surface; and *basso relievo*, low relief, or bas-relief properly so called, when the figures have not the prominence which their outline requires, but appears as if compressed. The principal objects of sculpture, are vases, *armatures*, or trophies, and the decorative parts of architecture.

Modelling.—Before any object is executed in stone, it is the practice of sculptors to complete a representation of their design, by modelling it in clay, or some other soft material. The genius of the artist is displayed altogether in the model; for the process of afterwards copying the model in stone, is chiefly mechanical, and may often be executed by another person, as well as by the sculptor himself. When a clay model is undertaken, if the proposed figure be large, a frame of wood or iron is erected to give support to the limbs and different parts of the figure. Upon this frame, a proper quantity of wet clay is distributed, and wrought into the form of the intended statue. The moulding of the clay is performed with the hands, and with various instruments of wood and ivory. When the model is completed, copies may be taken from it, either by casting them in plaster, or in metal; or by chiselling them in marble.

Casting in Plaster:—Copies are most frequently taken, both from new models, and from old statues, by casting them in plaster. For this purpose, a mould in plaster is first made from the surface of the statue, or figure, itself; and this mould is afterwards used to reproduce the figure

by casting. Plaster is prepared for use by pulverizing common gypsum, and exposing it to the heat of a fire until its moisture is wholly expelled.* While in this dry state, if it be mixed with water to the consistence of cream or paste, it has the property of hardening in a few minutes, and takes a very sharp impression. The hardness afterwards increases by keeping, till it approaches the character of stone.

Moulds are formed in the following manner. The statue or figure to be copied, is first oiled, to prevent it from cohering with the gypsum. A quantity of liquid plaster sufficient for the mould, is then poured on, immediately after being mixed, and is suffered to harden. If the subject be a bas-relief, or any figure which can be withdrawn without injury, the mould may be considered as finished, requiring only to be surrounded with an edging. But if it be a statue, it cannot be withdrawn, without breaking the mould ; and on this account it becomes necessary to divide the mould into such a number of pieces, as will separate perfectly from the original. These are taken off from the statue, and when afterwards replaced, or put together, without the statue, they constitute a perfect mould. This mould, its parts having been oiled to prevent adhesion, is made to receive a quantity of plaster, by pouring it in at a small orifice. The mould is then turned in every direction, in order that the plaster may fill every part of the surface ; and when a sufficient quantity is poured in to produce the strength required in the cast, the remainder is often left hollow, for the sake of lightness, and economy of the material. When the cast is dry, it is extricated by separating the pieces of the mould, and finished by removing the seams and blemishes with the proper tools.† If the form

* The heat requisite for this purpose must be greater than that of boiling water. Care must be taken not to raise the heat too high, as in that case the sulphate of lime would be decomposed.

† Plaster casts are varnished by a mixture of soap and white wax in boiling water. A quarter of an ounce of soap is dissolved in a pint of water, and an equal quantity of wax afterwards incorporated. The cast is dipped in this liquid, and after drying a week, is polished by rubbing with soft linen. The surface produced in this manner approaches to the polish of marble.

or position require it, the limbs are cast separately and afterwards cemented on.

Moulds and busts are obtained in a similar manner from living faces, by covering them with new plaster, and removing it in pieces as soon as it becomes hard. It is necessary that the skin of the face should be oiled, and, during the operation, the eyes are closed, and the person breathes through tubes inserted in the nostrils.

Elastic moulds have been formed by pouring upon the figure to be copied, a strong solution of glue. This hardens upon cooling, and takes a fine impression. It is then cut into suitable pieces and removed. The advantage of the elastic mould is that it separates more easily from irregular surfaces, or those with uneven projections and under cuttings, from which a common mould could not be removed without violence.*

Architectural models, and other complex pieces of workmanship, are made by casting the constituent parts separately, and afterwards cementing them together. If the form of the parts is complicated, a mould is required which can be taken to pieces to extract the cast. The cementing of the parts is performed by a thin mixture of plaster and water, recently made, and it is necessary that the surfaces to be joined should be thoroughly wet, before the cement is applied to them.

For small and delicate impressions, which are merely in relief, melted sulphur is sometimes used, also a strong solution of isinglass in proof spirit. The latter material has the advantage that it is not brittle when dry, but possesses a consistence like that of horn. Both substances yield very accurate and sharp impressions.

Bronze Casting.—Statues intended to occupy situa-

When plaster casts are to be exposed to the weather, their durability is greatly increased by saturating them with linseed oil, with which wax or rosin may be combined. When intended to resemble bronze, a soap is used, made of linseed oil and soda, colored by the sulphates of copper and iron. Walls and ceilings are rendered water proof in the same way. See an abstract of a memoir of D'Arcet and Thenard, in Brande's Journal, vol. xxii. 184, and Franklin Journal, ii. 276.

* See a paper by Mr. Fox, republished in the Franklin Journal, vol. iii.

tions in which they may be exposed to violence, are commonly made of bronze. This material resists both mechanical injuries, and decay from the influence of the atmosphere. The moulds in which bronze statues are cast, are made on the pattern, out of plaster and brick dust; the latter material being added to resist the heat of the melted metal. The parts of this mould are covered on their inside with a coating of clay, as thick as the bronze is intended to be. The mould is then closed, and filled on its inside with a nucleus, or core of plaster and brick dust, mixed with water. When this is done, the mould is opened, and the clay carefully removed. The mould with its core, are then thoroughly dried, and the core secured in its central position by short bars of bronze which pass into it through the external part of the mould. The whole is then bound with iron hoops, and when placed in a proper situation for casting, the melted bronze is poured in through an aperture left for the purpose. Of course, the bronze fills the same cavity which was previously occupied by the clay, and forms a metallic covering to the core. This is afterwards made smooth by mechanical means.

Practice of Sculpture.—To execute a statue in marble, which shall exactly correspond to a pattern or model, is a work of mechanical, rather than of inventive skill. It is performed by finding, in the block of marble, the exact situation of numerous points corresponding to the chief elevations and cavities in the figure to be imitated, and joining these by the proper curves and surfaces, at the judgement of the eye. These points are found, by measuring the height, depth, and lateral deviation of the corresponding points in the model; after which, those in the block are found by similar measurements. Sometimes the points are ascertained, by placing the model horizontally under a frame, and suspending a plumb-line successively from different parts of the frame, till it reaches the parts of the figure beneath it. Sometimes an instrument is used consisting of a movable point, attached by various joints to an upright post, so that it may be carried to any part of the statue, and indicate the relative position of that part

in regard to the post. Machines have also been contrived for cutting any required figure from a block, the cutting instrument being directed by a gauge which rests upon the model in another part of the machine.

Marble is wrought to the rough outline of the statue, by the chisel and hammer, aided by the occasional use of drills and other perforating tools. It is then smoothed with rasps and files, and when required, is polished with pumice-stone and putty. The hair of statues is always finished with the chisel ; and for this object, very sharp instruments with different points and edges are necessary. The ancient sculptors appear to have relied almost wholly upon the chisel, and to have used that instrument with great boldness and freedom, such as could have been justified only by consummate skill in the art. The moderns, on the contrary, approach the surface of the statue with great caution, and employ safer means for giving the last finish. Some of the most celebrated antique statues, such as the Laocoon, the Apollo Belvidere, and Venus de Medicis, are thought to have been finished with the chisel alone.

Materials.—Although marble has been the common material of sculpture, both in ancient and modern times, yet other substances have been occasionally made subjects of the chisel. Statues of porphyry, granite, serpentine, and alabaster, are found among the remains of antiquity. Other materials of a less durable kind, were also employed. Some of the principal works of Phidias were made of ivory and gold, particularly his colossal statues of Jupiter Olympius, and Minerva, at Athens.

Objects of Sculpture.—In sculpture, as in the other imitative arts, two ends propose themselves to the skill of the artist. One consists in the imitation of a particular object, in which case the art of the sculptor can be expected only to equal, but not to surpass, his original. The other consists in new combinations of excellence, and in the invention of forms and expressions, which are not known to exist together in nature, but are imbodied in the imagination of the artist. Beauty in objects thus conceived, constitutes the *beau ideal* in art, to attain

which, has ever been the ambition of cultivators of the fine arts. In statuary, the specimens which have descended to us from the ancient Greeks, are by universal consent admitted to be the most perfect designs of beauty, and furnish the common models for study and imitation, at the present, as in all former ages.

Gem Engraving.—The art of cutting precious stones, is more properly a species of sculpture, than of engraving. The hardness of these stones renders it impossible to operate on them by the strongest steel instruments. They are therefore wrought in a slow manner, by grinding them away upon the surface of a wheel, commonly made of metal, and covered with the grit, or fine powder, of some hard substance. The diamond can only be ground, or cut, with its own dust. Rubies, agates, emeralds, &c., are cut and polished with emery or tripoli, in fine powder. Lapidaries make use of small wheels, balls, and drills, of various forms, made of iron, or copper, which revolve with great rapidity, and act upon the stone through the medium of the pulverized material on their surface. They also use wires covered with emery, for the purpose of sawing plates.

The imitative designs, which are cut upon hard stones, are chiefly of two kinds. The first of these are *cameos*, which are little bas-reliefs or figures, raised above the surface. They are commonly made from stones, the strata of which are of different colors, so that the raised figure is of a different color from the ground to which it is attached. Varieties of agate, carnelian, onyx, &c., are made use of for this purpose. Sometimes several successive strata of different colors, are so wrought as to produce the appearance of painting. A cheaper kind of cameos are made from marine shells. These, having lime for their basis, may be scratched with steel, or corroded with acids. *Intaglios* are the second kind of engraved gems. They differ from cameos in having the figure cut into, or below, the surface, so that they serve as seals to produce impressions in relief upon soft substances.

Mosaic.—Mosaics are imitations of paintings made by

combining together an infinite number of minute stones of different colors, and cementing them on a plane surface. In the most costly mosaics, precious stones have been cut, and arranged to produce this effect. But in common works of this art, enamels of different colors, manufactured for the purpose, are the material employed. The enamel is first formed into sticks, from the ends of which, pieces of the requisite size are cut or broken off. These are confined in their proper places upon a plate of metal or stone, by a cement made of quicklime, pulverized limestone, and linseed oil. After the whole has adhered, it is allowed to dry two months, and is then polished with a flat stone and emery.* *Inlaid works* of agate, and other costly stones, are executed on the same principle as mosaic; except that the stones are larger, and cut to the shape of different parts of the object to be represented; whereas in mosaic, the pieces are of the same size and shape. The *opus reticulatum* of the ancients, with which columns and walls were sometimes incrusted, is found to consist of small stones, of a pyramidal form, the apex of which is imbedded in mortar, while the base, which is polished, forms the outer surface.

Scagliola.—This name is given at Rome, to a sort of artificial inlaid work, composed of plaster, but resembling stone. For works of this kind, gypsum, dried and powdered, is mixed with a solution of glue, and spread on a tablet for the ground of the picture. Cavities of the form intended in the design, are then made in it with an engraving tool. These are successively filled up with portions of plaster of different colors, so managed as to produce the effect of painting. In this way, buildings, and various natural objects, are represented. The surface is finely polished, by rubbing it with different powders, and, where the ground is white, with rushes.

* One of the largest mosaics which has been executed, is a copy of Leonardo da Vinci's celebrated picture of the Last Supper. It measures twenty-four feet by twelve, and employed eight or ten artists for eight years. It was executed under the direction of Raffaelli, at Milan, by order of the French government.—*Cadell.*

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CHAPTER XI.

OF ARCHITECTURE AND BUILDING.

ARCHITECTURE.—Elements, Foundations, Column, Wall, Lintel, Arch, Abutments, Arcade, Vault, Dome, Plate II., Roof, Styles of Building, Definitions, Measures, Drawings, Restorations, *Egyptian Style*, *The Chinese Style*, *The Grecian Style*. ORDERS OF ARCHITECTURE.—Doric Order, Ionic Order, Corinthian Order, Caryatides, Grecian Temple, Grecian Theatre, Remarks, *Roman Style*, Tuscan Order, Roman Doric, Roman Ionic, Composite Order, Roman Structures. Remarks, *Greco-Gothic Style*, *Saracenic Style*, *Gothic Style*, Definitions, Application.

ARCHITECTURE.—Architecture, in its most general sense, is the art of erecting buildings, of any kind. In modern use, this name is sometimes restricted to the external forms, or styles, of building, in which sense, architecture is one of the fine arts. It appears to have been among the earliest inventions, and its works have been commonly regulated by some principle of hereditary imitation. Whatever rude structure the climate and materials of any country have obliged its early inhabitants to adopt for their temporary shelter, the same structure, with all its prominent features, has been afterwards kept up by their refined and opulent posterity. Thus, the Egyptian style of building has its origin in the *cavern* and *mound*;* the Chinese architecture is modelled from the *tent*; the Grecian, is derived from the wooden *cabin*, and the Gothic, from the *bower* of trees.

Elements.—The essential elementary parts of a build-

* Wilkins's Vitruvius, p. xvii.

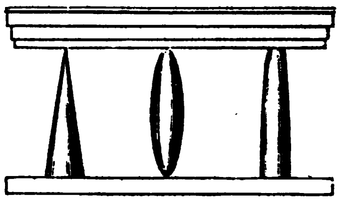
ing, are those which contribute to its support, enclosure, and covering. Of these, the most important are the foundation, the column, the wall, the lintel, the arch, the vault, the dome, and the roof.

Foundations.—In laying the foundation of any building, it is necessary to dig to a certain depth in the earth, to secure a solid basis, below the reach of frost and common accidents. The most solid basis is rock, or gravel which has not been moved. Next to these, are clay and sand, provided no other excavations have been made in the immediate neighborhood. From this basis, a stone wall is carried up to the surface of the ground, and constitutes the foundation. Where it is intended that the superstructure shall press unequally, as at its piers, chimneys, or columns, it is sometimes of use to occupy the space between the points of pressure, by an inverted arch. This distributes the pressure equally, and prevents the foundation from springing between the different points. In loose or muddy situations, it is always unsafe to build, unless we can reach the solid bottom below. In salt marshes and flats, this is done by depositing timbers, or driving wooden piles, into the earth, and raising walls upon them. The preservative quality of the salt, will keep these timbers unimpaired for a great length of time, and makes the foundation equally secure with one of brick or stone.

Column.—The simplest member in any building, though by no means an essential one to all, is the *column* or *pillar*. This is a perpendicular part, commonly of equal breadth and thickness, not intended for the purpose of enclosure, but simply for the support of some part of the superstructure. The principal force which a column has to resist, is that of perpendicular pressure. In its shape, the shaft of a column should not be exactly cylindrical; but since the lower part must support the weight of the superior part, in addition to the weight which presses equally on the whole column, the thickness should gradually decrease from bottom to top. The outline of columns should be a little curved, so as to represent a portion of a very long spheroid, or parabolid, rather than

of a cone. This figure is the joint result of two calculations, independent of beauty of appearance. One of these is, that the form best adapted for stability of base, is that of a cone. The other is, that the figure which would be of equal strength throughout for supporting a superincumbent weight, would be generated by the revolution of two parabolas round the axis of the column, the vertices of the curves being at its extremities.*

Fig. 21.



In the accompanying wood cut, No. 1 is the figure having the greatest stability of base; 2, the figure which is of equal strength throughout for resisting vertical pressure; and 3, the intermediate, or common form of the column, a little more curved than is usual in practice, and having its top truncated, to give stability to the entablature.

The swell of the shafts of columns, was called the *entasis*, by the ancients. It has been lately found,† that the columns of the Parthenon, at Athens, which have been commonly supposed straight, deviate about an inch from a straight line, and their greatest swell is at about one third of their height.

Columns in the antique orders are usually made to diminish one sixth, or one seventh, of their diameter, and sometimes even one fourth. The Gothic pillar is commonly of equal thickness throughout.

Wall.—The *wall*, another elementary part of a building, may be considered as the lateral continuation of a

* See Tredgold's Principles of Carpentry, p. 50.

† By Messrs Allanson and Cockerel. See Brande's Journal, vol. x. p. 204.

column, answering the purpose both of enclosure and support. A wall must diminish as it rises, for the same reasons, and in the same proportion, as the column. It must diminish still more rapidly if it extends through several stories, supporting weights at different heights. A wall, to possess the greatest strength, must also consist of pieces, the upper and lower surfaces of which are horizontal and regular, not rounded nor oblique. The walls of most of the ancient structures, which have stood to the present time, are constructed in this manner, and frequently have their stones bound together with bolts and cramps of iron. The same method is adopted in such modern structures as are intended to possess great strength and durability; and in some cases the stones are even dovetailed together, as in the light-houses at Eddystone, and Bell Rock. But many of our modern stone walls, for the sake of cheapness, have only one face of the stone squared, the inner half of the wall being completed with brick; so that they can in reality be considered only as brick walls faced with stone. Such walls are said to be liable to become convex outwardly, from the difference in the shrinking of the cement.

Rubble walls are made of rough, irregular stones laid in mortar. The stones should be broken, if possible, so as to produce horizontal surfaces. The *coffer* walls of the ancient Romans were made by enclosing successive portions of the intended wall in a box, and filling it with stones, sand, and mortar, promiscuously. This kind of structure must have been extremely insecure. The Pantheon, and various other Roman buildings, are surrounded with a double brick wall, having its vacancy filled up with loose bricks and cement. The whole has gradually consolidated into a mass of great firmness. The *reticulated* walls of the Romans, having bricks with oblique surfaces, would at the present day be thought highly unphilosophical. Indeed they could not long have stood, had it not been for the great strength of their cement.

Modern brick walls are laid with great precision, and depend for firmness more upon their position than upon

the strength of their cement. The bricks being laid in horizontal courses, and continually overlaying each other, or *breaking joints*, the whole mass is strongly interwoven, and bound together. When the bricks do not break joints, it is sometimes practised to insert thin pieces of iron between the tiers. Wooden walls, composed of timbers covered with boards, are a common, but more perishable kind. They require to be constantly covered with a coating of a foreign substance, as paint or plaster, to preserve them from spontaneous decomposition.

In some parts of France, and elsewhere, a kind of wall is made of earth, rendered compact by ramming it in moulds or cases. This method is called building in *Pisé*, and is much more durable than the nature of the material would lead us to suppose.

Walls of all kinds are greatly strengthened by angles and curves, also by projections, such as pilasters, chimneys, and buttresses. These projections serve to increase the breadth of the foundation, and are always to be made use of in large buildings, and in walls of considerable length.

Lintel.—The lintel, or beam, extends in a right line over a vacant space, from one column or wall to another. The strength of the lintel will be greater in proportion as its transverse vertical diameter exceeds the horizontal, the strength being always as the square of the depth. [See page 124.] The *floor* is the lateral continuation or connection of beams by means of a covering of boards.

Arch.—The arch is a transverse member of a building answering the same purpose as the lintel, but vastly exceeding it in strength. The arch, unlike the lintel, may consist of any number of constituent pieces, without impairing its strength. It is, however, necessary that all the pieces should possess a uniform shape, the shape of a portion of a wedge; and that the joints, formed by the contact of their surfaces, should point towards a common centre. In this case, no one portion of the arch can be displaced or forced inward; and the arch cannot be broken by any force which is not sufficient to crush the materials of which it is made. In arches made of common bricks, the sides of which are parallel, any *one* of the

bricks might be forced inward, were it not for the adhesion of the cement. Any *two* of the bricks, however, constitute a wedge, by the disposition of their mortar, and cannot collectively be forced inward. An arch of the proper form, when complete, is rendered stronger, instead of weaker, by the pressure of a considerable weight, provided this pressure be uniform. While building, however, it requires to be supported by a *centring* of the shape of its internal surface, until it is complete. The upper stone of an arch is called the *key-stone*, but is not more essential than any other.

A brick arch has been erected without *centring*, by laying pieces of hoop iron between the courses, which serve to bind the whole strongly together.

In regard to the shape of the arch, its most simple form is that of the semicircle. [Pl. II. Fig. *k*.] It is, however, very frequently a smaller arc of a circle, and still more frequently a portion of an ellipse. The simplest theory of an arch supporting itself only, is that of Dr. Hooke. The arch, when it has only its own weight to bear, may be considered as the inversion of a chain, suspended at each end. The chain hangs in such a form, that the weight of each link or portion is held in equilibrium by the result of two forces acting at its extremities; and these forces, or tensions, are produced, the one by the weight of the portion of the chain below the link, the other by the same weight increased by that of the link itself, both of them acting originally in a vertical direction. Now, supposing the chain inverted, so as to constitute an arch of the same form and weight, the relative situations of the forces will be the same, only they will act in contrary directions, so that they are compounded in a similar manner, and balance each other on the same conditions. The arch thus formed, is denominated a *catenary* arch. [Pl. II. Fig. *l*.] In common cases it differs but little from a circular arch of the extent of about one third of a whole circle, and rising from the abutments with an obliquity of about thirty degrees from a perpendicular.

But though the catenary arch is the best form for supporting its own weight, and also all additional weight

which presses in a vertical direction, it is not the best form to resist lateral pressure, or pressure like that of fluids, acting equally in all directions. Thus the arches of bridges and similar structures, when covered with loose stones and earth, are pressed sidewise, as well as vertically, in the same manner as if they supported a weight of fluid. In this case, it is necessary that the arch should arise more perpendicularly from the abutment, and that its general figure should be that of the longitudinal segment of an ellipse. [Pl. II. Fig. *m*.] In small arches in common buildings, where the disturbing force is not great, it is of little consequence what is the shape of the curve. The outlines may even be perfectly straight, as in the tier of bricks which we frequently see over a window. This is, strictly speaking, a real arch, provided the surfaces of the bricks tend towards a common centre. [Pl. II. Fig. *s*.] It is the weakest kind of arch, and a part of it is necessarily superfluous, since no greater portion can act in supporting a weight above it, than can be included between two curved or arched lines.

Besides the arches already mentioned, various others are in use. The *acute* or *lancet* arch, [Pl. II. Fig. *o*,] much used in Gothic architecture, is described usually from two centres outside the arch. It is a strong arch for supporting vertical pressure. The *rampant* arch [Fig. *n*] is one, in which the two ends spring from unequal heights. The *horse-shoe* or *Moorish* arch [Fig. *p* and *q*] is described from one or more centres placed above the base line. In this arch, the lower parts are in danger of being forced inward. The *ogee* arch [Fig. *r*] is concavo-convex, and therefore fit only for ornament.

In describing arches, the upper surface is called the *extrados*, and the inner, the *intrados*. The *springing* lines are those where the intrados meets the abutments, or supporting walls. The *span* is the distance from one springing line to the other. The wedge-shaped stones which form an arch, are sometimes called *voussoirs*, the uppermost being the keystone. [Pl. II. Fig. *k*.] The part of a pier from which an arch springs, is called the *impost*, and the curve formed by the upper side of the voussoirs, the *archivolt*.

Abutments.—It is necessary that the walls, abutments, and piers, on which arches are supported, should be so firm as to resist the lateral *thrust*, as well as vertical pressure, of the arch. It will at once be seen that the lateral or sideway pressure of an arch is very considerable, when we recollect that every stone, or portion of the arch, is a wedge, a part of whose force acts to separate the abutments. For want of attention to this circumstance, important mistakes have been committed, the strength of buildings materially impaired, and their ruin accelerated. In some cases, the want of lateral firmness in the walls, is compensated by a bar of iron stretched across the span of the arch and connecting the abutments, like the tie beam of a roof. This is the case in the cathedral of Milan, and some other Gothic buildings.*

Arcade.—In an arcade, or continuation of arches, it is only necessary that the outer supports of the terminal arches should be strong enough to resist horizontal pressure. In the intermediate arches, the lateral force of each arch is counteracted by the opposing lateral force of the one contiguous to it. In bridges, however, where individual arches are liable to be destroyed by accident, it is desirable, that each of the piers should possess sufficient horizontal strength, to resist the lateral pressure of the adjoining arches.

Vault.—The vault is the lateral continuation of an arch, serving to cover an area, or passage, and bearing the same relation to the arch, that the wall does to the column. A simple vault is constructed on the principles of the arch, and distributes its pressure equally along the walls, or abutments. A complex or *groined* vault is made by two vaults intersecting each other; in which case, the pressure is thrown upon springing points, and is greatly increased at those points. The groined vault is common in Gothic architecture.

Dome.—The dome, sometimes called *cupola*, is a concave covering to a building, or part of it, and may be either a segment of a sphere, of a spheroid, or of any similar figure. When built of stone, it is a very strong kind

* Cadell's Journey through Carniola and Italy, vol. ii. p. 77.

of structure, even more so than the arch, since the tendency of each part to fall, is counteracted, not only by those above and below it, but also by those on each side. It is only necessary that the constituent pieces should have a common form, and that this form should be somewhat like the frustum of a pyramid, so that when placed in its situation, its four angles may point toward the centre, or axis, of the dome. During the erection of a dome, it is not necessary that it should be supported by a centring, until complete, as is done in the arch. Each circle of stones, when laid, is capable of supporting itself, without aid from those above it. It follows, that the dome may be left open at top, without a key-stone, and yet be perfectly secure, in this respect, being the reverse of the arch. The dome of the Pantheon, at Rome, has been always open at top, and yet has stood unimpaired for nearly two thousand years. The upper circle of stones, though apparently the weakest, is nevertheless often made to support the additional weight of a lantern or tower above it. In several of the largest cathedrals, there are two domes, one within the other, which contribute their joint support to the lantern which rests upon the top. In these buildings, the dome rests upon a circular wall, which is supported in its turn by arches upon massive pillars or piers. This construction is called building upon *pendentives*, and gives open space and room for passage, beneath the dome.

The remarks which have been made in regard to the abutments of the arch, apply equally to the walls immediately supporting a dome. They must be of sufficient thickness and solidity to resist the lateral pressure of the dome, which is very great. The walls of the Roman Pantheon are of great depth and solidity. In order that a dome in itself should be perfectly secure, its lower parts must not be *too* nearly vertical, since in this case, they partake of the nature of perpendicular walls, and are acted upon by the spreading force of the parts above them. The dome of St. Paul's church, in London, and some others of similar construction, are bound with chains or hoops of iron, to prevent them from spreading at bottom. Domes

which are made of wood, depend in part for their strength, on their internal carpentry. The Halle du Bled, in Paris, had, originally, a wooden dome more than two hundred feet in diameter, and only one foot in thickness. This has since been replaced by a dome of iron.

Plate H.—In this plate is given a comparative view in outline of some of the most remarkable domes in ancient and modern buildings, together with the edifices to which they belong, likewise various other structures reduced to the same scale.

The highest dome, [No. 3,] is that of St. Peter's church at Rome, generally considered the most splendid building in the world, and one of the largest in size. This edifice was a century in building, from about 1510 to 1610. It was begun by Bramante, and finished by Michael Angelo and Vignola. The dome is of an ellipsoidal form, solid at bottom, but divided into two thin, concentric domes at top, between which is the stair leading to the lantern. The whole height from the ground to the cross at top, is about four hundred and seventy feet. The base of the dome rests upon arches, supported by massive stone piers. Within the last century, some fissures of dangerous appearance were discovered in this dome; to remedy which, it was surrounded with iron chains by the artist Zabaglia.

The next dome in height, [No. 4,] is that of the church of St. Maria del Fiore, at Florence. Its vertical section is an elongated ellipsoid, its horizontal section octagonal. This church is about three hundred and eighty feet high, and was built between 1298 and 1472. The dome was erected by Bruneleschi, one of the earliest revivers of antique architecture.

St. Paul's cathedral, London, [No. 5,] was erected by Sir Christopher Wren, between 1685 and 1710. It has two domes at different heights, the inner being made of brick, and the outer of wood. Between the two, is a hollow, truncated cone of brick-work, which furnishes the support of the lantern at top. The outline of the dome is somewhat more than a semicircle, and is prevented from spreading at bottom, by a strong iron hoop.

The church of St. Genevieve, in Paris, [No. 6,] which, during the absence of the Bourbon family, was called the Pantheon, was begun by Soufflot, in 1757. This edifice has been threatened with ruin, in consequence of the piers, which support the dome, being made too small for the nature of the material, and the superincumbent weight. It became necessary to replace a part of the stones which were crushed, and to increase the amount of support, to obtain present security.

The mosque of St. Sophia, at Constantinople, [No. 7,] presents a specimen of the kind of dome used by the ancients, which was more flat than any of the preceding examples, and was usually a small segment of a sphere. This edifice was erected during the reign of Justinian, in the sixth century. Owing to the want of sufficient solidity in the supporting wall, the dome fell down at two successive times, and the architect was under the necessity of filling up the subjacent arcades, and of building large buttresses on the outside of the wall, to resist the pressure, and give to the dome eventual stability. The span of this dome is one hundred and twelve feet.

The Pantheon, at Rome, [No. 8,] is probably the oldest dome now standing, and is one of the best constructed. Its outer and inner surfaces are of different curvatures, so that the thickness increases downward, the inner surface being a hemisphere. The walls of this edifice are of great solidity, and to this circumstance the security of the superstructure is in part owing. This dome is open at the top. It was built by Agrippa, in the reign of Augustus Cæsar. A more perfect view of the Pantheon is given in Fig. 45, on p. 286.

The outline of St. Mark's church, at Venice, which has several domes; that of the front of the Parthenon, at Athens, which shows the lowness of the Grecian pediment; that of the restored temple of Vesta, at Tivoli; and, lastly, that of the small Ionic temple which stood upon the Ilissus, are added merely to give an idea of their comparative size. The column erected to the memory of the emperor Trajan, also one of the obelisks brought from Egypt by the ancient Romans, are introduced upon the same scale.

No. 1, in the same plate, represents the outline of the largest of the Egyptian Pyramids, respecting the dimensions of which, travellers vary greatly in their accounts. One of the more moderate of their estimates is here taken, which makes the height a little less than five hundred feet.

No. 2, shows the length and height of the Colosseum, at Rome, a vast elliptical amphitheatre, which fifteen thousand men were occupied ten years in completing. It was built in the reign of Vespasian and Titus, and its walls are standing at the present day.

No. 15, represents the celebrated leaning tower of Pisa. The several stories of this structure are supported by arcades upon columns, in the Greco-gothic style. The height of the whole is one hundred and eighty feet. This tower leans over about fourteen feet from a perpendicular. The view here taken of it, does not represent its greatest inclination. Whether the obliquity was the effect of design, or of the settling of the foundation on one side, is a point upon which writers are not agreed. It was built in the twelfth century.

No. 16, is the steeple of the Gothic cathedral, at Strasburg. It is among the highest steeples in Europe, and is introduced to show its comparative elevation. No. 17, is the centre steeple of the *Duomo* or Cathedral of Milan, about three hundred and fifty feet high. This edifice is of white marble. Its general character is Gothic, intermixed with details in the later Roman style.

The proportions of most of the foregoing buildings are taken from Durand, who has reduced them to a scale. The same scale applies to the other architectural plates in this volume, with the exception of perspective representations, in which more than one side is seen.

The outlines of several American edifices, reduced to the same scale, are added in this plate, for the convenience of comparison. No. 18, is that of the Capitol, at Washington, built of freestone, the length of which is three hundred and fifty feet, the height of the front seventy feet, and the height of the centre dome one hundred and forty-eight feet. No. 19, is the City Hall, at New York, built chiefly of marble; its length two hundred and twenty

feet, and the height of the statue at top, one hundred and twenty feet. No. 20, is the State House, in Boston, one hundred and seventy-three feet in length, built of brick, and painted. No. 21, is the Bank of the United States, at Philadelphia, a marble building, having its front eighty-six feet wide, copied in most respects from the Parthenon at Athens. No. 22, the monument erected at Baltimore, in commemoration of the battle and victory at that place. Height about fifty-five feet.

Roof.—The *roof* is the most common and cheap method of covering buildings, to protect them from rain and other effects of the weather. It is sometimes flat, but more frequently oblique in its shape. The flat or platform roof is the least advantageous for shedding rain, and is seldom used in northern countries. The *pent* roof, consisting of two oblique sides meeting at top, is the most common form. [Pl. II. Fig. *w*.] These roofs are made steepest in cold climates, where they are liable to be loaded with snow. Where the four sides of the roof are all oblique, it is denominated a *hipped* roof, [Fig. *x*;] and where there are two portions to the roof, of different obliquity, it is a *curb*, or *mansard* roof. [Fig. *y*.] In modern times, roofs are made almost exclusively of wood, though frequently covered with incombustible materials. The internal structure or carpentry of roofs, is a subject of considerable mechanical contrivance. The roof is supported by *rafters*, which abut on the walls on each side, like the extremities of an arch. If no other timbers existed, except the rafters, they would exert a strong lateral pressure on the walls, tending to separate and overthrow them.* To counteract this lateral force, a *tie beam*, as it is called, extends across, receiving the ends of the rafters, and protecting the wall from their

* The largest roof that has hitherto been built, is supposed to have been that of the riding house, at Moscow. Its span was two hundred and thirty-five feet, and the slope of the roof, about nineteen degrees. The principal support of this immense truss, consisted in an arch of timber in three thicknesses, indented together, and strapped and bolted with iron. The principal rafters and tie beams, were supported by several vertical pieces, notched to this arch, and the whole stiffened by diagonal braces.—*Tredgold's Carpentry*, p. 87.

horizontal thrust. To prevent the tie beam from *sagging*, or bending downward with its own weight, a *king post* is erected from this beam, to the upper angle of the rafters, serving to connect the whole, and to suspend the weight of the beam. This is called *trussing*. *Queen posts* are sometimes added, parallel to the king post, in large roofs; also various other connecting timbers. In Gothic buildings, where the vaults do not admit of the use of a tie beam, the rafters are prevented from spreading, as in an arch, by the strength of the buttresses.

In comparing the lateral pressure of a high roof, with that of a low one, the length of the tie beam being the same, it will be seen that a high roof, from its containing most materials, may produce the greatest pressure, as far as weight is concerned. On the other hand, if the weight of both be equal, then the low roof will exert the greater pressure, and this will increase in proportion to the distance of the point at which perpendiculars drawn from the end of each rafter, would meet.

In roofs, as well as in wooden domes, and bridges, the materials are subjected to an internal strain, to resist which the cohesive strength of the material is relied on. On this account, beams should, when possible, be of one piece. Where this cannot be effected, two or more beams are connected together by *splicing*. Spliced beams are never so strong as whole ones, yet they may be made to approach the same strength, by affixing lateral pieces, or by making the ends overlay each other, and connecting them with bolts and straps of iron. The tendency to separate is also resisted, by letting the two pieces into each other, by the process called *scarfing*. *Mortises*, intended to *truss* or suspend one piece by another, should be formed upon similar principles.

Roofs in this country, after being boarded, receive a secondary covering of shingles. When intended to be incombustible, they are covered with slates or earthen tiles or with sheets of lead, copper or tinned iron. Slates are preferable to tiles, being lighter, and absorbing less moisture. Metallic sheets are chiefly used for flat roofs, wooden domes, and curved and angular surfaces, which require a

flexible material to cover them, or have not a sufficient pitch to shed the rain from slates or shingles. Various artificial compositions are occasionally used to cover roofs, the most common of which are mixtures of tar with lime, and sometimes with sand and gravel.

Styles of Building.—The architecture of different countries has been characterized by peculiarities in external form, and in modes of construction. These peculiarities, among ancient nations, were so distinct, that their structures may be identified even in the state of ruins; and the origin and era of each may be conjectured with tolerable accuracy. Before we proceed to describe architectural objects, it is necessary to explain certain terms, which are used to denote their different constituent portions. The architectural *orders* will be spoken of under the heads of the Grecian and Roman styles, but their component parts ought previously to be understood.

Definitions.—The front or *façade* of a building, made after the ancient models, or any portion of it, may present three parts, occupying different heights.

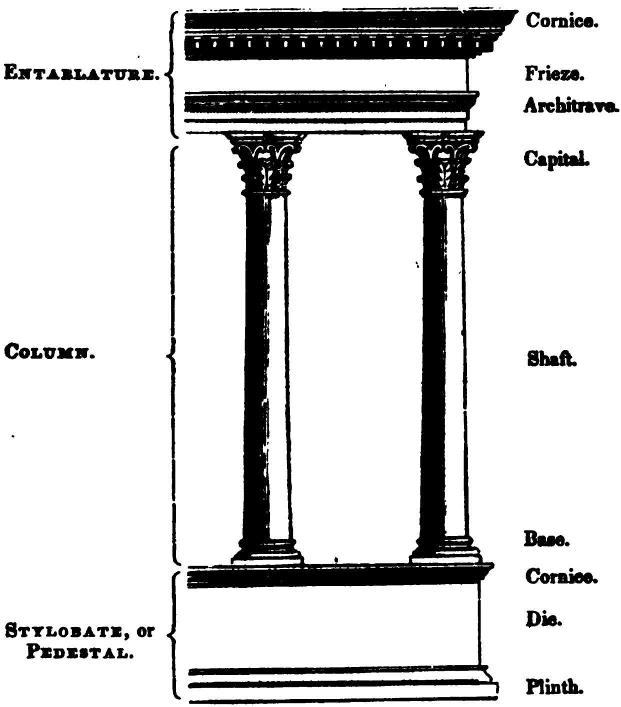
The *pedestal* is the lower part, usually supporting a column. The single pedestal is wanting in most antique structures, and its place supplied by a *stylobate.* The stylobate is either a platform with steps, or a continuous pedestal, supporting a row of columns. The lower part of a finished pedestal is called the *plinth*,* the middle part is the *die*, and the upper part the *cornice* of the pedestal, or *surbase.*

The *column*, is the middle part, situated upon the pedestal or stylobate. It is commonly detached from the wall, but is sometimes buried in it for half its diameter, and is then said to be *engaged.* *Pilasters* are square or flat columns, attached to walls. The lower part of a column, when distinct, is called the *base*; the middle, or longest part, is the *shaft*, and the upper, or ornamented part, is the *capital.* The height of columns is measured in diameters of the column itself, taken always at the base.

* The name plinth, in its general sense, is applied to any square projecting basis, such as those at the bottom of walls, and under the base of columns.

The *entablature*, is the horizontal, continuous portion, which rests upon the top of a row of columns. The lower part of the entablature is called the *architrave*, or *epistylium*. The middle part is the *frieze*, which, from its usually containing sculpture, was called *zophorus* by the ancients. The upper, or projecting part, is the *cornice*.

Fig. 22.



A *pediment*, is the triangular face, produced by the extremity of a roof. The middle, or flat portion, enclosed by the cornice of the pediment, is called the *tympanum*. Pedestals for statues, erected on the summit and extremities of a pediment, are called *acroteria*. See

temple of Antoninus and Faustina. An *attic*, is an upper part of a building, terminated at top by a horizontal line, instead of a pediment.

The different *mouldings* in architecture are described from their sections, or from the profile which they present, when cut across. Of these, the *torus* [Plate II. *a*] is a convex moulding, the section of which is a semicircle, or nearly so. The *astragal*, [*b*,] is like the torus, but smaller. The *ovolo*, [*c*,] is convex, but its outline is only the quarter of a circle. The *echinus*, [*d*,] resembles the ovolo, but its outline is spiral, not circular. The *scotia*, [*e*,] is a deep, concave moulding. The *cavetto*, [*f*,] is also concave, and occupying but a quarter of a circle. The *cymatium*, [*g*,] is an undulated moulding, of which the upper part is concave, and the lower convex. The *ogee talon*, [*h*,] is an inverted cymatium. The *fillet*, [*i*,] is a small, square or flat moulding.*

Measures.—In architectural measurement, a *diameter* means the width of a column at the base. A *module* is half a diameter. A *minute* is a sixtieth part of a diameter.

Drawings.—In representing edifices by drawings, architects make use of the *plan*, *elevation*, *section*, and *perspective*. The *plan* is a map, or design, of a horizontal surface, showing the ichnographic projection, or groundwork, with the relative position of walls, columns, doors, &c.† The *elevation* is the orthographic projection of a front, or vertical surface; this being represented, not as it is actually seen in perspective, but as it would appear if seen from an infinite distance. The *section* shows the interior of a building, supposing the part in front of an intersecting plane to be removed. The *perspective* shows the building as it actually appears to the eye, subject to the laws of scenographic perspective. The three former are used by architects, for purposes of admeasurement; the latter is used also by painters, and is capable of bring-

* By a singular mixture of derivations, the Greek, Latin, Italian, French, and English languages are laid under contribution for the technical terms of Architecture.

† See various plans of temples, on pages 275, 276, 277.

ing more than one side into the same view, as the eye actually perceives them.

Restorations.—As the most approved features in modern architecture are derived from buildings which are more or less ancient, and as many of these buildings are now in too dilapidated a state to be easily copied, recourse is had to such imitative restorations in drawings and models, as can be made out from the fragments and ruins which remain. In consequence of the known simplicity and regularity of most antique edifices, the task of restoration is less difficult than might be supposed. The groundwork, which is commonly extant, shows the length and breadth of the building, with the position of its walls, doors, and columns. A single column, whether standing or falling, and a fragment of the entablature, furnish data from which the remainder of the colonnade, and the height of the main body, can be made out. A single stone from the cornice of the pediment, is often sufficient to give the angle of inclination, and consequently the height of the roof. In this way, beautiful restorations are obtained of structures, when in so ruinous a state, as scarcely to have left one stone upon another.

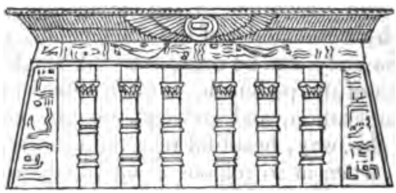
EGYPTIAN STYLE.

In ancient Egypt, a style of building prevailed, more massive and substantial than any which has succeeded it. The elementary features of Egyptian architecture, were chiefly as follows. 1. Their walls were of great thickness, and sloping on the outside. This feature is supposed to have been derived from the mud walls, mounds, and caverns of their ancestors. 2. The roofs and covered ways were flat, or without pediments, and composed of blocks of stone, reaching from one wall or column to another. The principle of the arch, although known to them, was seldom employed by them. 3. Their columns were numerous, close, short, and very large, being sometimes ten or twelve feet in diameter. They were generally without bases, and had a great variety of capitals, from a simple square block, ornamented with hieroglyphics, or faces, to an elaborate composition of palm leaves

not unlike the Corinthian capital. 4. They used a sort of concave entablature, or cornice, composed of vertical flutings, or leaves, and a winged globe in the centre. 5. Pyramids, well known for their prodigious size, and obelisks composed of a single stone, often exceeding seventy feet in height, are structures peculiarly Egyptian. 6. Statues of enormous size, sphinxes carved in stone, and sculptures in outline of fabulous deities and animals, with innumerable hieroglyphics, are the decorative objects which belong to this style of architecture.

The subjoined figure (23) represents an ancient Egyptian temple at Essenay.

Fig. 23.



An idea may be formed from the plates of travellers, of the general plan of the great Egyptian temples. 1. An avenue of sphinxes. 2. Two colossal figures on each side of a gateway, formed by immense towers of truncated pyramids, with overhanging cornices. 3. This gateway led into a court full of columns, and chambers round the walls. 4. Passing across this, the visiter comes to other courts, likewise full of columns, through gateways, ornamented with colossal figures and obelisks. 5. In the centre was the sanctuary, absolutely without light. These sanctuaries often consisted of a single excavated block. They are called Monolithic temples, and one has been described by the ancients, at the temple of Latona, as forty cubits broad in front, carved out of one entire stone, and roofed by another. Semiramis is said to have brought from the mountains of Arabia a rock twenty cubits broad, and one hundred and fifty long. The Monolithic temple, engraved by Denon, is a mere upright parallelogram, with

an aperture in the side. Little private sacella, or chapels, were likewise annexed to the larger Egyptian temples.

The architecture of the ancient Hindoos, appears to have been derived from the same original ideas as the Egyptian. The most remarkable relics of this people, are their subterraneous temples, of vast size and elaborate workmanship, carved out of the solid rock, at Elephanta, Ellora, and Salsette.

THE CHINESE STYLE.

The ancient Tartars, and wandering shepherds of Asia, appear to have lived from time immemorial in *tents*, a kind of habitation adapted to their erratic life. The Chinese have made the tent the elementary feature of their architecture; and of their style any one may form an idea, by inspecting the figures which are depicted upon common china ware. Chinese roofs are concave on the upper side, as if made of canvass instead of wood. A Chinese portico is not unlike the awnings spread over our shop windows in summer time. The *verandah*, sometimes copied in dwellinghouses here, is a structure of this sort. The Chinese towers and pagodas, have concave roofs, like awnings, projecting over their several stories. The lightness of the style used by the Chinese, leads them to build with wood, sometimes with brick, and seldom with stone. The following figure (24) represents the octagonal pagoda of Sinkicien, in China.

Fig. 24.

THE GRECIAN STYLE.

Grecian achitecture, from which have been derived the most splendid structures of later ages, has its origin in the wooden hut or cabin, formed of posts set in the earth, and covered with transverse poles and rafters. Its beginnings were very simple, being little more than imitations, in stone, of the original posts and beams. By degrees these were modified and decorated, so as to give rise to the distinction of what are now called the *orders* of architecture.

Orders of Architecture.—By the architectural orders, are understood certain modes of proportioning and decorating the column and its entablature. They were in use during the best days of Greece and Rome, for a period of six or seven centuries. They were lost sight of in the dark ages, and revived again by the Italians at the time of the restoration of letters. The Greeks had three orders, called the *Doric*, *Ionic* and *Corinthian*. These were adopted and modified by the Romans, who also added two others, called the *Tuscan* and *Composite*.

Doric Order.—The Doric is the earliest and most massive order of the Greeks. It is known by its large columns with plain capitals, its *triglyphs* resembling the ends of beams, and its *mutules* corresponding to those of rafters. The column, in the examples at Athens, is about six diameters in height. In the older examples, as those at Pæstum, it is but four or five. The shaft had no base, but stood directly on the stylobate. It had twenty flutings, which were superficial, and separated by angular edges. The perpendicular outline was nearly straight. The Doric capital was plain, being formed of a few *annulets*, or rings, a large *echinus*, and a flat stone at top called the *abacus*. The architrave was plain; the frieze was intersected by oblong projections called *triglyphs*, divided into three parts by vertical furrows, and ornamented beneath, by *guttæ*, or drops. The spaces between the triglyphs were called *metopes*, and commonly contained sculptures. The sculptures representing Centaurs and Lapithæ, carried by Lord Elgin to London, were me-

topes of the Parthenon or temple of Minerva, at Athens. The cornice of the Doric order consisted of a few large mouldings, having on their under side a series of square, sloping projections, resembling the ends of rafters, and called *mutules*. These were placed over both triglyphs and metopes, and were ornamented, on their under side, with circular *guttæ*. The best specimens of the Doric order, are found in the Parthenon, the Propylæa, and the Temple of Theseus, at Athens. [Figs. 33, 34, 35, 36, 37, 38.]

Ionic Order.—The Ionic is a lighter order than the Doric, its column being eight or nine diameters in height. It had a base often composed of a torus, a scotia, and a second torus, with intervening fillets. This is called the *Attic* base. [Fig. 70.] Others were used in different parts of Greece. The shaft had twenty-four, or more, flutings, which were narrow, as deep as a semicircle, and separated by a fillet or square edge. The capital of this order consisted of two parallel double scrolls, called *volutes*, occupying opposite sides, and supporting an abacus, which was nearly square, but moulded at its edges.

Fig. 25.

These volutes have been considered as copied from ringlets of hair, or perhaps from the horns of Jupiter Ammon. When a column made the angle of an edifice, its volutes were placed, not upon opposite, but on contiguous sides; each fronting outward. In this case, the volutes interfered with each other at the corner, and were obliged to assume a diagonal direction. The Ionic entablature consisted of an architrave and frieze, which were continuous or unbroken, and a cornice of various successive mouldings, at the lower part of which was often a row of *dentels* or square teeth. The examples at Athens, of the Ionic order, are the temple of Erec-

theus, and the temple on the Ilissus, which was standing in Stuart's time, seventy years since, but is now extinct. [Figs. 70, 25, 40, 41, 42.]

Corinthian Order.—The Corinthian was the lightest and most decorated of the Grecian orders. Its base resembled that of the Ionic, but was more complicated. The shaft was often ten diameters in height, and was fluted like the Ionic. The capital was shaped like an inverted bell, and covered on the outside with two rows of leaves of the plant acanthus,* above which were eight pairs of small volutes. Its abacus was moulded and concave on its sides, and truncated at the corners, with a flower on the centre of each side. The entablature of the Corinthian order, resembled that of the Ionic, but was more complicated and ornamented, and had, under the cornice, a row of large oblong projections, bearing a leaf or scroll on their under side, and called *modillions.* No vestiges of this order are now found in the remains of Corinth, and the most legitimate example at Athens, is in the choragic monument of Lysicrates, [Fig. 43.] The Corinthian order was much employed in the subsequent structures of Rome, and its colonies, [Figs. 71, 45, 46, 47, &c.]

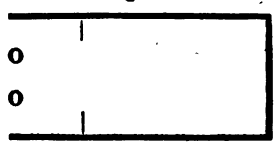
Caryatides.—The Greeks sometimes departed so far from the strict use of the orders, as to introduce statues, in the place of columns, to support the entablature. Statues of slaves, heroes, and gods, appear to have been employed occasionally for this purpose. The principal specimen of this kind of architecture, which remains, is in a portico, called Pandroseum, attached to the temple of Erectheus, at Athens, in which statues of Carian females, called *Caryatides*, are substituted for columns. [Fig. 41.] One of these statues has been carried to London.

Grecian Temple.—The most remarkable public edifices of the Greeks, were their temples. These, being

* The origin of the Corinthian capital has been ascribed to the sculptor Callimachus, who is said to have copied it from a basket accidentally enveloped in leaves of acanthus. A more probable supposition traces its origin to some of the Egyptian capitals, which it certainly resembles.

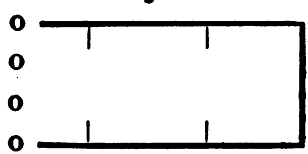
intended as places of resort for the priests, rather than for the convening of assemblies within, were in general obscurely lighted. Their form was commonly that of an oblong square, having a colonnade without, and a walled *cell* within. The cell was usually without windows, receiving its light only from a door at the end, and sometimes from an opening in the roof. The part of the colonnade which formed the front portico, was called the *pronaos*, and that which formed the back part, the *posticus*. The colonnade was subject to great variety in the number and disposition of its columns, from which Vitruvius has described seven different species of temples. These were, 1. The temple with *antæ*. In this, the front was composed of pilasters, called antæ, on the sides, and two columns in the middle.

Fig. 26.



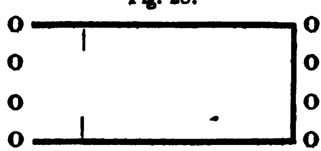
2. The *Prostyle*. This had a row of columns at one end only.

Fig. 27.



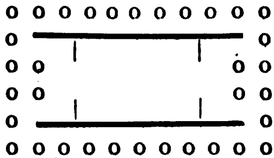
3. The *Amphiprostyle*, having a row of columns at each end.

Fig. 28.



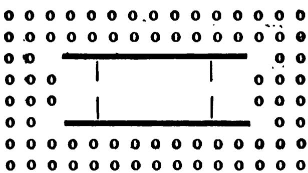
4. The *Peripteral* temple. This was surrounded by a single row of columns, having six in front, and in rear, and eleven, counting the angular columns, on each side.

Fig. 29.



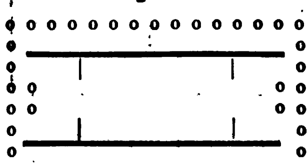
5. The *Dipteral*, with a double row of columns all round the cell, the front consisting of eight.

Fig. 30.



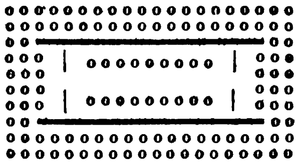
6. The *Pseudo-dipteral* differs from the dipteral, in having a single row of columns on the sides, at the same distance from the cell, as if the temple had been dipteral.

Fig. 31.



7. The *Hypæthral* temple had the centre of its roof open to the sky. It was colonnaded without, like the dipteral, but had ten columns in front. It had also an internal colonnade, called *peristyle*, on both sides of the open space, and composed of two stories or colonnades, one above the other.

Fig. 32.



Temples, especially small ones, were sometimes made of a circular form. When these were wholly open, or without a cell, they were called *Monopteral* temples. When there was a circular cell within the colonnade, they were called *Peripteral.**

Grecian Theatre.—The theatre of the Greeks, which was afterwards copied by the Romans, was built in the form of a horse-shoe, being semicircular on one side, and square on the other. The semicircular part, which contained the audience, was filled with concentric seats, ascending from the centre, to the outside. In the middle, or bottom, was a semicircular floor called the *orchestra*. The opposite, or square part, contained the actors. Within this was erected, in front of the audience, a wall ornamented with columns and sculpture, called the *scena.* The stage, or floor, between this part and the orchestra, was called the *proscenium.* Upon this floor was often erected a movable wooden stage, called, by the Romans, *pulpitum.* The ancient theatre was open to the sky, but a temporary awning was erected to shelter the audience from the sun and rain.

Remarks.—Grecian architecture is considered to have been in its greatest perfection in the age of Pericles and Phidias. The sculpture of this period, is admitted to have been superior to that of any other age; and although architecture is a more arbitrary art than sculpture, yet it is natural to conclude, that the state of things which gave

* The *intercolumniation*, or distance between the columns, according to Vitruvius, was differently arranged under the following names. In the *pycnostyle*, the columns were a diameter and a half apart. In the *systyle* they were two diameters apart. In the *diastyle*, three. In the *aræostyle*, more than three. In the *eustyle*, two and a quarter.

birth to excellence in the one, must have produced a corresponding power of conceiving sublimity and beauty in the other. Grecian architecture was, in general, distinguished by simplicity of structure, fewness of parts, absence of arches, lowness of pediments and roofs, and by decorative curves, the outline of which was a spiral line, or conic section, and not a circular arc, as afterwards adopted by the Romans.

The following drawings give a front view of various Grecian edifices, the remains of which are extant at the present day. The limits of the page permit only the front elevation to be given, which, in the oblong Grecian temples, was the end of the building.

Fig. 33.

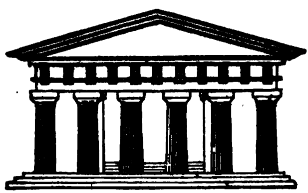


Fig. 33, represents the principle temple at Pæstum, in Italy. At this place are now standing, the walls and colonnades of three temples, built in the ancient Doric style, and undoubtedly erected by a Grecian colony in that country. The characters of this early Doric, are short and heavy columns, much diminished upwards, large capitals, and a massive entablature, nearly half as high as the columns. The outline of the columns in this building is straight, or without entasis. The temple appears to have been hypæthral, though the number of columns is less than in the rule prescribed by Vitruvius.

Fig. 34, is the Temple of Concord, commonly so called, at Agrigentum, now Girgenti, in Sicily. It is erected in the massive style of the older Doric, on a stylobate of four steps, and, with the exception of the roof, is in a state of good preservation at the present day. Other Doric ruins are found in the same place, also at Segesta,

Selinus, and other parts of Sicily. Views of these structures are given in Wilkins's *Magna Græcia.*

Fig. 34.

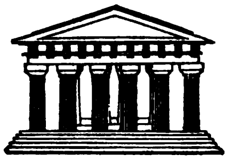


Fig. 35, is the Temple of Theseus, at Athens, situated in the lower part of that city, some way from the

Fig. 35.

Acropolis. It is the most perfectly preserved of any of the Athenian edifices, its columns and walls having suffered scarcely any dilapidation. At the top of its stone platform, or stylobate, it measures one hundred and four feet in length, by forty-five in breadth, and has six columns on each front, with thirteen on each side, counting those at the angles. The temple of Theseus was erected by Cimon, the son of Miltiades, about four hundred and fifty years before Christ. The sculptures upon the frieze of this building are supposed, by Stuart and others, to refer to the exploits of Theseus, but according to Mr. Wilkins,* they represent the labors of Hercules.

Fig. 36, is the Propylæa, at Athens, a structure of much beauty, which commanded the entrance to the Acropolis, or citadel. Besides a portico of six Doric columns on each front, it had an Ionic colonnade within, and a separate quadrangular building attached to each side. Before the entrance, are two large pedestals, sup-

* Topography and Buildings of Athens, 8vo. 1816.

Fig. 36.

posed to have supported equestrian statues. The Propylæa was ascended by steps at different stages, and had also an inclined plane for carriages. This building was erected in the time of Pericles, and is now in a ruinous state, a great portion of what remains being hidden by the walls of the Turks. Fig. 37, is a transverse section of the Propylæa, made at right angles with the former view, and showing the different ascents.

Fig. 37.

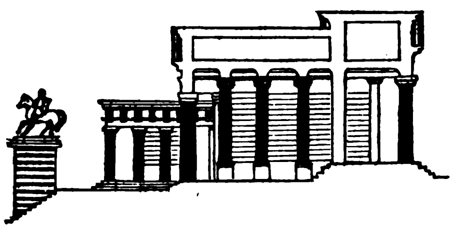
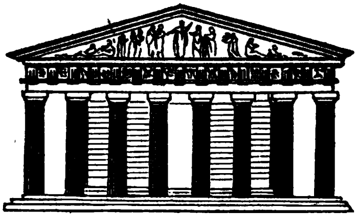


Fig. 38. is the façade of the Parthenon, or temple of Minerva, situated on the summit of the Acropolis, at Athens. This building is now considered the best model for the Doric order, and no edifice, ancient or modern, commands such general applause at the present day. It was built by the architect Ictinus, during the administration of Pericles, about four hundred and forty years before Christ. Its decorative sculptures are supposed to have been executed under the direction of Phidias. The platform or stylobate, consists of three steps, the uppermost of which is two hundred and twenty seven feet

Fig. 38.



in length, and one hundred and one in breadth. The number of columns is eight in the portico of each front, and seventeen on each flank, besides which there is an inner row of six columns at each end of the cell. The proportional height of the columns is five diameters and thirty-three minutes, and they diminish thirteen minutes in diameter, from bottom to top. The sculptures on the frieze represent the combats of the Centaurs and Lapithæ. Those on the eastern pediment, represented the fabulous birth of Minerva ; and those on the western, the contests between that goddess and Neptune, for the right of presiding over the city. When Athens was visited by Wheler, in 1676, the Parthenon remained entire, with the exception of its roof. But during the siege of the city by the Venetians, in 1687, a shell which exploded in the midst of the cell, destroyed the whole central part of the wall, together with nineteen of the columns. Most of the sculpture of both pediments has also disappeared.

Fig. 39.

Fig. 39, is the choragic monument of Thrasyllus, situated without the Acropolis, and constituting the front of a grotto. It is not, strictly speaking, of any architectural order, but departs from the Doric, in having a row of

circular wreaths, instead of triglyphs, and a continuous row of guttæ at the bottom of the frieze.

Fig. 40.

Fig. 40, is the small Ionic amphiprostyle temple on the banks of the Ilissus, which was standing in Stuart's time, but has now wholly disappeared. The delineations obtained from this building by Stuart, have since furnished the most popular models of the Ionic order.

Fig. 41.

Fig. 41, is the Erectheum, an Ionic building, much admired, in the Acropolis, at Athens. It comprises two temples, one dedicated to Minerva Polias, the other to the nymph Pandrosus. The smaller portico of the Pandroseum, is remarkable for a row of Caryatides, or female statues, which perform the office of columns in supporting the entablature.* Fig. 25, is an Ionic capital from the temple on the Ilissus. Those of the temple of Minerva Polias were similar in the general form of the volutes, but had also an ornamented neck above the flutings.

Fig. 42, represents the façade of the Temple of Apollo Didymæus, near Miletus. It was among the most celebrated Grecian structures. It was termed by Strabo, the greatest of all temples, and was ranked by Vitruvius, with that of Diana, at Ephesus. Although few of its columns are now standing, the ruins give evidence of its

* One of these statues was carried off by Lord Elgin, and is placed with other Athenian marbles in the British Museum. Stuart makes this building to consist of three temples, viz. those of Erectheus, Minerva Polias, and Pandrosus. Mr. Wilkins divides it into two.

Fig. 42.

original size and magnificence. It appears to have been a dipteral temple, surrounded with a double row of columns, triple in front, and in all one hundred and twelve. Views of this building are given in the Ionian antiquities, and in the *Voyage Pittoresque* of Choiseul Gouffier.

Fig. 43.

Fig. 43 is the choragic monument of Lysicrates, at Athens, sometimes improperly called the Lantern of Demosthenes. This elegant little structure has a circular ornamented roof of one stone, and six Corinthian columns engaged in a circular wall, the whole supported on a square basis. It is now half inclosed in a modern convent.

Fig. 44.

Fig. 44, is the octagon tower, at Athens, commonly called the *Tower of the Winds*, from the emblematic sculptures on its sides. Its sides are marked with lines, for indicating the hour of the day by the shadows of gnomons.

ROMAN STYLE.

Roman architecture had its origin in copies of the Greek models. All the Grecian orders were introduced into Rome, and variously modified. Their number was augmented by the addition of two new orders, the Tuscan and the Composite.

Tuscan Order.—This order, derived from the ancient Etruscans, is not unlike the Doric deprived of its triglyphs and mutules. It had a simple base containing one torus. Its column was seven diameters in height, with an astragal below the capital. Its entablature, somewhat like the Ionic, consisted of plain, running surfaces. There is no vestige of this order among ancient ruins, and the modern examples of it are taken from the descriptions of Vitruvius. [Fig. 67.]

Roman Doric.—The Romans modified the Doric order by increasing the height of its column to eight diameters. Instead of the echinus which formed the Grecian capital, they employed the ovolo, with an astragal and neck below it. They placed triglyphs over the centre of columns, not at the corners, and used horizontal mutules, or introduced foreign ornaments in their stead. The theatre of Marcellus has examples of the Roman Doric. [Fig. 69.]

Roman Ionic.—The Romans diminished the size of the volutes in the Ionic order. They also introduced a kind of Ionic capital in which there were four pairs of diagonal volutes, instead of two pairs of parallel ones. This they usually added to parts of some other capital, but at the present day it is often used alone, under the name of *modern* Ionic.

Composite Order.—This fifth order was made by the Romans out of the Corinthian, simply by combining its capital with that of the diagonal, or modern Ionic. [Fig.

72.] Its best example is found in the arch of Titus. The favorite order, however, in Rome and its colonies, was the Corinthian, and it is this order which prevails among the ruins, not only of Rome, but of Nismes, Pola, Palmyra, and Balbec.

Roman Structures.—The temples of the Romans, sometimes resembled those of the Greeks, but often differed from them. The *Pantheon*, which is the most perfectly preserved temple of the Augustan age, is a circular building, lighted only from an aperture in the dome, and having a Corinthian portico in front. The *amphitheatre* differed from the theatre, in being a complete circular, or rather elliptical building, filled on all sides with ascending seats for spectators, and leaving only the central space, called the *arena*, for the combatants and public shows. The Colosseum is a stupendous structure of this kind. The *aqueducts* were stone canals, supported on massive arcades, and conveying large streams of water, for the supply of cities. The *triumphal arches* were commonly solid oblong structures, ornamented with sculptures, and open with lofty arches for passengers below. The *basilica* of the Romans, was a hall of justice, used also as an exchange, or place of meeting for merchants. It was lined on the inside with colonnades of two stories, or with two tiers of columns, one over the other. The earliest Christian churches at Rome, were sometimes called basilicæ, from their possessing an internal colonnade. The monumental *pillars*, were towers in the shape of a column on a pedestal, bearing a statue on the summit, which was approached by a spiral staircase within. Sometimes, however, the column was solid. The *thermæ*, or baths, were vast structures, in which multitudes of people could bathe at once. They were supplied with warm and cold water, and fitted up with numerous rooms, for purposes of exercise and recreation.

Remarks.—In several particulars, the Roman copies differed from the Greek models, on which they were founded. The stylobate, or substructure, among the Greeks, was usually a plain succession of platforms, constituting an equal access of steps, to all sides of the

building. Among the Romans, it became an elevated structure, like a continued pedestal, accessible by steps only at one end. The spiral curve of the Greeks, was exchanged for the geometrical circular arc, as exemplified in the substitution of the ovolo for the echinus in the Doric capital. The changes in the orders, have been already mentioned. After the period of Hadrian, Roman architecture is considered to have been on the decline. Among the marks of a deteriorated style, introduced in the later periods, were columns with pedestals, columns supporting arches, convex friezes, entablatures squared so as to represent the continuation of the columns, pedestals for statues projecting from the sides of columns, niches covered with little pediments, &c.

The following buildings in the Roman style, are reduced to a scale, after Durand. They are all of the Corinthian order.

Fig. 45.

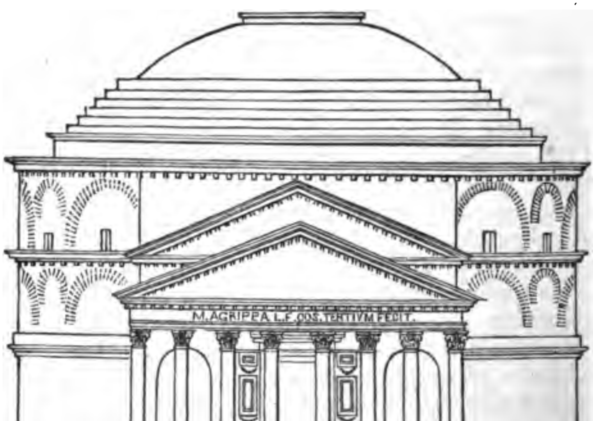


Fig. 45, is the Pantheon, already mentioned, of which the portico is of stone, while the body, or circular part

covered by the dome, is of brick. The occurrence in this building, of two pediments, one above the other, is considered a defect, and probably indicates that the parts of the edifice were erected at different times. The entablature consists only of a cornice. In most other respects, the symmetry of this building is much admired.

Fig. 46.

Fig. 46, is the temple of Antoninus and Faustina, at Rome. The walls and columns are raised upon an elevated stylobate, and are approached by steps in front only, differing in this respect from the Grecian temples, which were accessible on all sides.

Fig. 47.

Fig. 47, is the *Maison carrée* at Nismes, in France. It is psuedo-peripteral, having its columns engaged in the wall, with the exception of ten, which form the portico in front. It has been lately discovered that this building

which remains in excellent preservation, was erected to the memory of Caius and Lucius Cæsar, sons of Agrippa, and grandsons of Augustus.*

Fig. 48.

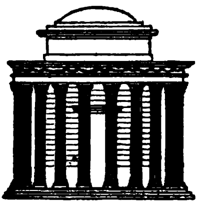


Fig. 48, is the circular peripteral temple of Vesta, at Rome. The temple of Vesta, at Tivoli, differs from this, in having a raised stylobate. The dome, in both these buildings, is an imaginary restoration, made after the rules of Vitruvius. Messrs. Taylor and Cresy have given to the temple at Tivoli, a conical roof, like that of the monument of Lysicrates.

Fig. 49.

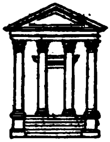
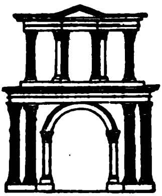


Fig. 49, is a temple at Pola, in Istria, dedicated to Rome and Augustus. At this place are many interesting antiquities, among which are an amphitheatre and triumphal arch.

Fig. 50, is the structure commonly called the Arch of Theseus, at Athens. It was erected probably by the

* The origin and date of this beautiful temple were unknown, until an artist, named Seguier, made out the inscription on the frieze, by connecting together the holes in which the nails were driven, that formerly confined bronze letters upon the wall.

Fig. 50.



Roman emperor Hadrian, to divide the new city from the old, and bears an inscription on each side, indicating that on one side is seen the city of Theseus, and on the other the city of Hadrian.

Fig. 51.

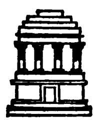


Fig. 51, is a sepulchre at Mylassa, in Asia Minor, apparently of Roman origin, and described in the Ionian antiquities. Its angular pillars are square, but the intermediate columns have a form very unusual in ancient or modern architecture, being compressed, so that a section of the shaft represents an ellipse. They are fluted for half their length.

Fig. 52.

Fig. 52, is the triumphal arch of Constantine, at Rome,

which, with the exception of a part of its sculptures, is entire at the present day. This arch was built after the arts had begun to decline, and is constructed chiefly of materials taken from the arch of Trajan, erected two centuries before. Its columns stand upon separate, projecting pedestals, and have a part of the entablature squared upon the top of each.

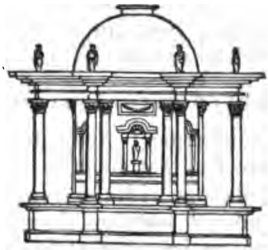
Fig. 53.

Fig. 53, is the external portico of the Temple of the Sun, at Palmyra. The ruins of this city exceed in extent and magnificence anything else which remains of antiquity in Europe, or Asia. It is built in the Corinthian order, and in the later style of Roman architecture, characterized by niches in the walls at different heights, containing statues; by numerous small pediments and entablatures; also in some cases by statues supported on brackets, or pedestals projecting from the sides of columns. In this portico, an example occurs of double columns, a feature rarely met with, in antique architecture, but sometimes used by the moderns, upon an extensive scale.*

Fig. 54, is the circular temple at Balbec, a place distinguished by the magnificence and colossal size of its

* To the regular duplicature of columns introduced in the colonnade of the Louvre, in Paris, Perrault has given the name of *aræo-systile*. See note, p. 277.

Fig. 54.



ruins. This temple is singular in the form of its outline, which is circular, with large concave recesses between all the columns, as shown more distinctly in the ground plan, Fig. 55, of the same building. In other respects it partakes of the later Roman style.

Fig. 55.

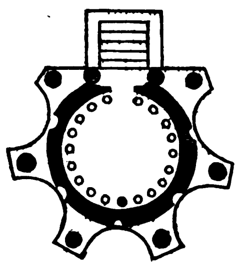


Fig. 56.

Fig. 56, is the octagonal temple of Jupiter, forming part of the palace erected by the Roman emperor Diocletian, at Salona, now Spalatro, in Dalmatia, where its extensive ruins are still extant.

GRECO-GOTHIC STYLE.

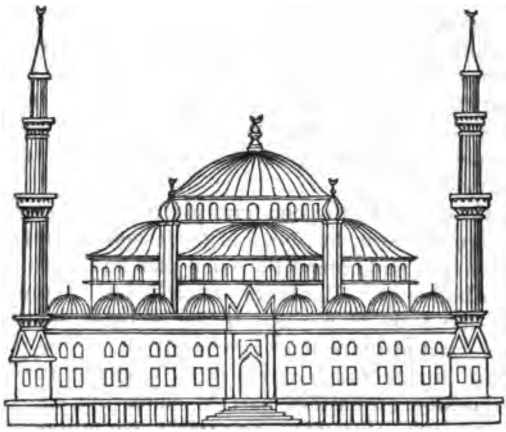
After the dismemberment of the Roman empire, the arts degenerated so far, that a custom became prevalent of erecting new buildings with the fragments of old ones, which were dilapidated and torn down for the purpose. This gave rise to an irregular style of building, which continued to be imitated, especially in Italy, during the dark ages. It consisted of Grecian and Roman details, combined under new forms, and piled up into structures wholly unlike the antique originals. Hence the names *Greco-gothic* and *Romanesque* architecture have been given to it. It frequently contained arches upon columns, forming successive arcades, which were accumulated above each other to a great height. The effect was sometimes imposing. The cathedral and leaning tower, at Pisa, and the church of St. Mark, at Venice, are cited as the best specimens of this style. [Pl. II. No. 15, and Fig. 74.] The Saxon architecture, used anciently in England, has some things in common with this style.

SARACENIC STYLE.

The edifices erected by the Moors and Saracens in Spain, Egypt, and Turkey, are distinguished, among other things, by a peculiar form of the arch. This is a curve, constituting more than half of a circle, or ellipse. This construction of the arch, is unphilosophical, and comparatively insecure. A similar peculiarity exists in the domes of the oriental Mosques, which are sometimes large segments of a sphere, appearing as if inflated; and at other times concavo-convex in their outline, as in the mosque of Achmet, in Constantinople, represented in the figure which follows. [57.] It has a central dome, surrounded by four half domes, which cover vast recesses resembling niches. Its court is surrounded by a sort of

cloister, covered by numerous small cupolas, and having minarets at the angles and sides. The *minaret* is a

Fig. 57.



tall, slender tower, peculiar to Turkish architecture. A peculiar flowery decoration, called *arabesque*, is common in the Moorish buildings of Europe, and Africa. [Pl. II. Fig. *p* and *q*, Fig. 77.]

GOTHIC STYLE.

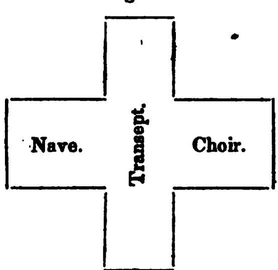
The Goths, who plundered Rome, had nothing to do with the invention of Gothic architecture. The name was introduced by Sir Christopher Wren, and others, as a term of reproach, to stigmatize the edifices of the middle ages, which departed from the purity of the antique models. The term was, at first, very extensive in its application, but it is now confined chiefly, to what may be called the modern Gothic,—the style of building cathedrals, churches, abbeys, &c. which was introduced in England six or eight centuries ago, and adopted, nearly at the same time, in France, Germany, and other parts of Europe. The Gothic style is peculiar and strongly marked. Its principle seems to have originated in the imitation of groves, and bowers, under which the Druids

performed their sacred rites. Its characteristics, at sight, are, its pointed arches, its pinnacles and spires, its large buttresses, clustered pillars, vaulted roofs, profusion of ornaments, and the general predominance of the perpendicular over the horizontal.

Although the Gothic style of building was originated at a period, when the arts were less successfully cultivated than they were in the time of the Greeks, it has nevertheless given rise to some of the most lofty, the most highly decorated, and the most imposing structures now in existence.

Definitions.—As the common place for the display of Gothic architecture, has been in ecclesiastical edifices, it is necessary to understand the usual plan and construction of these buildings. A church or cathedral is commonly built in the form of a cross, having a tower, lantern, or spire, erected at the place of intersection. The part of the cross, situated toward the west, is called the *nave*. The opposite, or eastern part, is called the *choir*, and within this is the *chancel*. The transverse portion, forming the arms of the cross, is called the *transept*.

Fig. 58.



Any high building erected above the roof, is called a *steeple*; if square topped, it is a *tower*; if long and acute, a *spire*, and if short and light, a *lantern*. Towers of great height, in proportion to their diameter, are called *turrets*. The walls of Gothic churches, are supported, on the outside, by lateral projections, extending from top to bottom, at the corners, and between the windows.

These are called *buttresses*, and they are rendered necessary to prevent the walls from spreading under the enormous weight of the roofs. [Figs. 59, and 60.] On the tops of the buttresses, and elsewhere, are slender pyramidal structures, or spires, called *pinnacles*. These are ornamented on their sides, with rows of projections, appearing like leaves or buds, which are named *crockets*. The summit, or upper edge of a wall, if straight, is called a *parapet*; if indented, a *battlement*. Gothic windows were commonly crowned with an acute arch. They were long and narrow, or if wide, were divided into perpendicular lights by *mullions*. The lateral spaces on the upper and outer side of the arch, are called *spandrells*; and the ornaments in the top, collectively taken, are the *tracery*. An *oriel*, or *bay window*, is a projecting window. A *wheel*, or *rose window*, is large and circular. A *corbel*, is a bracket or short projection from a wall, serving to sustain a statue, or the springing of an arch.

Gothic *pillars* or columns, are usually clustered, appearing as if a number were bound together. The single shafts thus connected, are called *boltels*. They are confined chiefly to the inside of buildings, and never support anything like an entablature. Their use is to aid in sustaining the vaults under the roof, which rest upon them at springing points. [Fig. 61]. Gothic vaults intersect each other, forming angles called *groins*. The parts which are thrown out of the perpendicular, to assist in forming them, are the *pendentives*. The ornamented edge of the groined vault, extending diagonally, like an arch, from one support to another, is called the *ogyve*. The gothic term *gable*, indicates the erect end of a roof, and answers to the Grecian pediment, but is more acute.

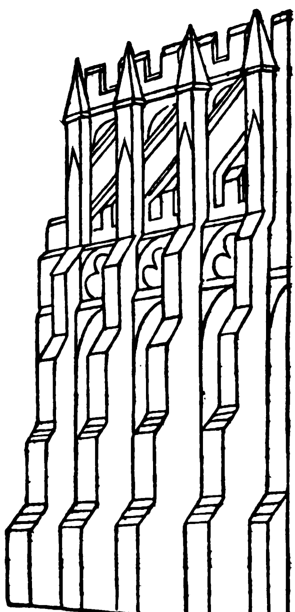
The Gothic style of building is more imposing, and more difficult to execute, than the Grecian. This is because the weight of its vaults and roofs is upheld at a great height, by supporters acting at single points, and apparently but barely sufficient to effect their object. Great mechanical skill is necessary, in balancing and sustaining the pressures; and architects at the present day,

find it difficult to accomplish what was achieved by the builders of the middle ages.

Fig. 59.

Fig. 59, is a perspective view of York cathedral, one of the most admired specimens of Gothic architecture. It is built in the form of a cross, and has three towers,

Fig. 60.



of which the two front ones are surmounted by pinnacles, and the central one by battlements. It was built between the years 1171 and 1426.

Fig. 60, is a Gothic exterior, from the wall of Westminster Abbey, showing the buttresses, which support the walls; also the short pinnacles and battlements. The slanting braces at top are called *flying buttresses.*

Fig. 61.

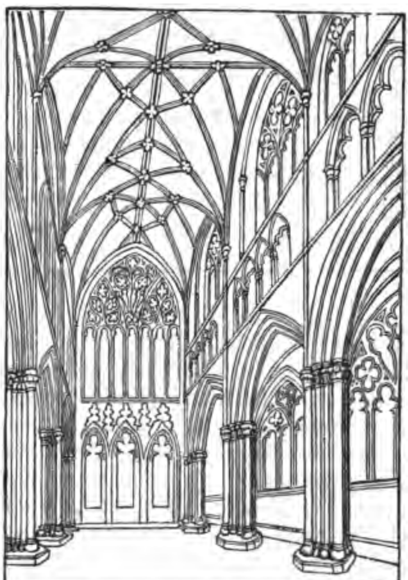
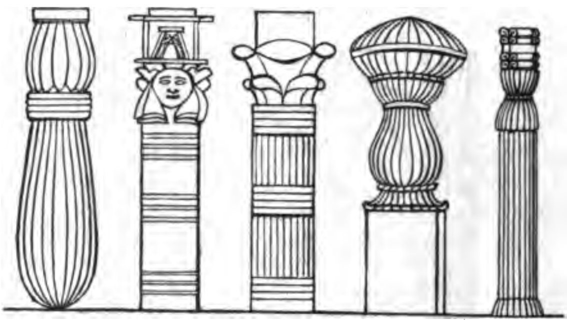


Fig. 61, is a Gothic interior, from the nave of York cathedral. It shows the clustered pillars, pointed arches, groined vaulting, and tracery, which belong to the Gothic style.

In the following figures, is presented a series of columns, with some of their entablatures, arches, &c., illustrative of the styles of building which have prevailed in different epochs, and countries. The first three figures are those of Egyptian columns, all serving to show the massiveness of

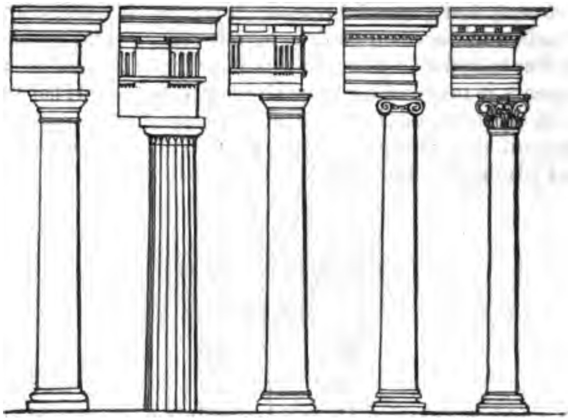
structure which prevailed in the buildings of that nation. A great variety of these columns exist at the present day in Upper Egypt, particularly at Karnac and Luxor, the remains of ancient Thebes. Fig. 62, is from a tomb of Silsilis, and has an outline which is common among the

Fig. 62. Fig. 63. Fig. 64. Fig. 65. Fig. 66.



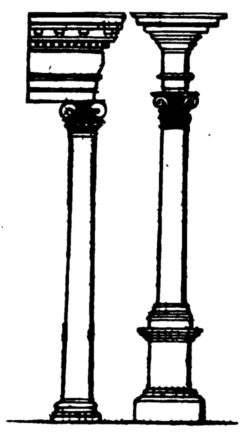
Egyptian ruins.—Fig. 63, likewise a common form, has a capital composed of faces. Fig. 64, is a column from Komonbu. The idea of the Corinthian capital, seems to have been borrowed from Egyptian specimens of this kind. The column, Fig. 65, is from the great cave at Elephanta, near Bombay, one of the wonderful subterranean structures excavated by the ancient inhabitants of Hindostan out of solid rock. Fig. 66, is a column from the ruins of Persepolis. At this place, which contains the most remarkable relics of the ancient arts of Persia, the style of architecture partakes of the Egyptian and Hindoo characteristics, the columns, however, being more slender. Fig. 67, represents the Tuscan order, used by the ancient inhabitants of Etruria. Fig. 68, is the Grecian Doric, of the age of Pericles, at which time it is considered to have been in greatest perfection. Fig. 69, is the Roman Doric, represented with a base, after the restorations of the moderns. Fig. 70, is the Grecian Ionic. The base represented in this figure, and the next, is called the *Attic base.*—Fig. 71, the Corinthian

Fig. 67. Fig. 68. Fig. 69. Fig. 70. Fig. 71.



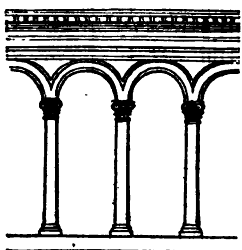
order. Fig. 72, the Composite order, in which the volutes are larger than in the Corinthian. The modern Ionic is taken from the upper part of this capital. The frieze is represented as convex, a feature which is considered peculiar to the later or declining period of Roman archi-

Fig. 72. Fig. 73.



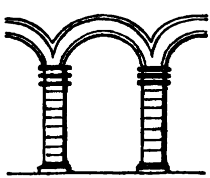
tecture. Fig. 73, is a combination of the column with a pedestal, and a squared portion of the entablature, usually attached to the main edifice, by one side. This peculiarity was introduced after the arts had begun to decline, and appears in many of the later Roman edifices. It has been absurdly imitated in more modern times, by making a squared entablature to constitute a portion of the column, and placing another entablature above it. Fig. 74, shows

Fig. 74.



a mode of building with arches between the columns and the entablature. It is taken from the remains of Diocletian's palace at Spalatro, and seems to have given rise to the Greco-gothic style. Fig. 75, which also exhibits

Fig. 75.



arches upon columns, is a specimen of Saxon architecture from the cathedral at Ely. Fig. 76, is a twisted column from a cloister belonging to St. Paul's church, without the walls, at Rome, rebuilt about the year 800. Columns of this sort occur in various Italian structures, but it is difficult to conceive of a form more at variance with architectural fitness or security. Fig. 77, Moorish

double columns, arches, and arabesques, from the Alhambra, at Granada. In the same building, the true Saracenic, or horse-shoe arch, also occurs. Fig. 78, a Gothic pillar from Salisbury cathedral. Other Gothic

Fig. 76.

Fig. 77.

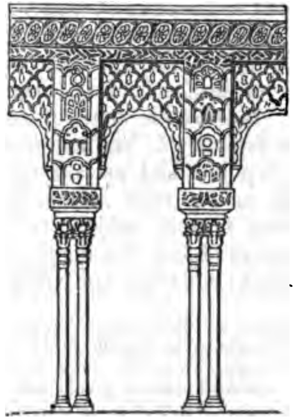
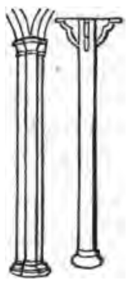
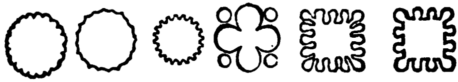


Fig. 78. Fig. 79.



forms are seen in Fig. 79, a Chinese column from the viceroy's palace, at Canton, Fig. 80, section of a reeded Egyptian column, Fig. 81, section of a fluted Doric column, Fig. 82, section of a fluted Ionic column, and Figs. 83, 84, and 85, sections of different Gothic columns.

Fig. 80. Fig. 81. Fig. 82. Fig. 83. Fig. 84. Fig. 85.



Application.—In edifices erected at the present day, the Grecian and Gothic outlines are commonly employed, to the exclusion of the rest. In choosing between them, the fancy of the builder, more than any positive rule of fitness, must direct the decision. Modern dwellinghouses have necessarily a style of their own, as far as stories and

apartments, and windows and chimneys, can give them one. No more of the styles of former ages can be applied to them, than what may be called the unessential and decorative parts. In general, the Grecian style, from its right angles and straight entablatures, is more convenient, and fits better with the distribution of our common edifices, than the pointed and irregular Gothic. The expense, also, is generally less, especially if anything like thorough and genuine Gothic is attempted; a thing, however, rarely undertaken, as yet, in this country. But the occasional introduction of the Gothic outline, and the partial employment of its ornaments, has undoubtedly an agreeable effect, both in public and private edifices; and we are indebted to it, among other things, for the spire, a structure exclusively Gothic, which, though often misplaced, has become an object of general approbation, and a pleasing landmark to our cities and villages.

WORKS OF REFERENCE.—WILKINS's Translation of Vitruvius, 4to. 1817;—ELMES' Lectures on Architecture, 8vo. 1823;—STUART's Antiquities of Athens, 4 vols. fol. 1762, &c.;—Antiquities of Ionia, by the DILETTANTI SOCIETY, 2 vols. fol. 1817-21;—Antiquities of Attica, by the same, fol. 1817;—WILKINS's Magna Græcia, fol. 1807;—DESGODETZ's buildings of Rome, 2 vols. fol. tra. 1771; —TAYLOR and CRESYS' Antiquities of Rome, 2 vols. fol. 1821-2;—DURAND, *Recueil des Edifices*, oblong fol. 1801;—PUGINS' Specimens of Gothic Architecture, 2 vols. 4to. 1823;—BRITTONS' Architectural Antiquities of Great Britain, 4 vols. 4to. 1815, &c.;—TREDGOLD's Elements of Carpentry, 4to. 1821;—NICHOLSON's Architectural Dictionary, 3 vols. 4to. 1821.

CHAPTER XII.

ARTS OF HEATING AND VENTILATION.

PRODUCTION OF HEAT.—Fuel, Weight of Fuel, Combustible Matter of Fuel, Water in Fuel, Charcoal. *Communication of Heat*, Radiated and Conducted Heat, Fire in the Open Air, Fire Places, Admission of Cold Air, Open Fires, Franklin Stove, Rumford Fire Place, Double Fire Place, Coal Grate, Anthracite Grate, Burns's Grate, Building a Fire, Furnaces, Stoves, Russian Stove, Cockle, Thermometer Stove, Carrying Heat, Heating by Air Flues, Heating by Water, Heating by Steam, *Retention of Heat*, Causes of Loss, Crevices, Chimneys, Entries and Sky Lights, Windows, *Ventilation*, Objects, Modes, Ventilators, Culverts, Smoky Rooms, Damp Chimneys, Large Fire Places, Close Rooms, Contiguous Doors, Short Chimneys, Opposite Fire Places, Neighboring Eminences, Turncap, &c., Contiguous Flues, Burning of Smoke, General Remarks.

IN cold and temperate climates, a large portion of human labor is devoted to procure and sustain such a degree of heat, as is necessary to a comfortable existence. The means of effecting this object, as far as the economy of fires and dwellinghouses is concerned, will be considered in the present chapter. To procure heat, to distribute it, to retain it, and to obviate its attendant inconveniences by ventilation, are the principal objects that present themselves in a survey of the subject.

PRODUCTION OF HEAT.

Fuel.—Heat is artificially obtained, for common purposes, by the combustion of fuel. Fuel may be usefully considered with regard to its compactness, or weight, its quantity of combustible matter, and its quantity of water.

Weight of Fuel.—In regard to the first consideration, if other things be equal, the more compact and heavy any fuel is, the more difficult it is to kindle, but the more permanent will it be found, when once on fire. Coal, for example, is a compact fuel, when compared with light, dry wood. Coal cannot so well be kindled by a small blaze,

nor by a very small quantity of other combustible matter on fire, because its density renders it a rapid conductor, and it carries off the heat of the kindling substance, so as to extinguish it, before it is itself raised to the temperature necessary for its combustion. But, if the heat of other fuel be applied to it, in sufficient quantity, and long enough, to ignite it, it then produces a powerful fire, and a much more durable one, than lighter fuel. Light fuel, on the other hand, being a slow conductor of heat, kindles easily; and, from the admixture of atmospheric air in its pores and crevices, burns out rapidly, producing a comparatively short, though often a strong heat.

Combustible matter of Fuel.—The quantity of combustible matter of fuel is important, and if the weight and other circumstances be equal, it may be learnt from the ashes, or residuum, left after the combustion. For example,—good Newcastle coal contains a greater portion of combustible matter than some of the Virginia coals, and leaves behind a smaller amount of earthy and incombustible substance. The heating power, and consequent value, of different kinds of fuel, is affected by this circumstance, though by no means dependent on it. The fitness of fuel, for various purposes, is furthermore affected by the facility, with which it gives off a part of its combustible matter, in the form of vapor, or gas; which, being burnt in that state, produces *flame*.* For example, the bituminous coals abound in volatile matter, which, when ignited, supports a powerful blaze. On the other hand, the Lehigh, and other anthracite coals, are destitute of bitumen, and yield but little flame. It is from similar causes, that dry pine wood produces a powerful blaze, while its charcoal yields comparatively little. A blaze is of great service, where heat is required to be applied to an extensive surface, as in reverberating furnaces, ovens, glasshouses, &c. But, when an equable, condensed, or lasting, fire is wanted, the more solid fuels which blaze less, are to be preferred.

Water in Fuel.—The quantity of watery fluid con-

* See Chapter IX., Art. *Flame.*

tained in fuel, greatly affects the amount of heat it produces, much more, indeed, than is commonly admitted in practice. It is a well-known law of chemistry, that the evaporation of liquids, or their conversion into steam, consumes, and renders latent, a great amount of caloric. When green wood, or wet coal, are added to the fire, they abstract from it, by degrees, a sufficient part of its heat, to convert their own sap, or moisture, into steam, before they are capable of being burnt. And, as long as any considerable part of this fluid remains unevaporated, the combustion goes on slowly, the fire is dull, and the heat feeble. Green wood commonly contains a third, or more, of its weight of watery fluid; the quantity varying, according to the greater or less porosity of different trees. Nothing is further from true economy, than to burn green wood, or wet coal, on the supposition that, because they are more durable, they will, in the end, prove more cheap. It is true, their consumption is less rapid; but, to produce a given amount of heat, a far greater amount of fuel must be consumed. Wood that is dried under cover, is better than wood dried in the open air, being more free from decomposition.

Not only the production of steam, but likewise the formation of different gases, which are evolved during combustion, affect the usefulness of fuel, according to their quantity and capacity for heat. It is difficult, however, to estimate with accuracy, the amount of their practical effect.

Charcoal.—Charcoal is prepared from wood, and *coke* in a similar manner from pitcoal, by raising those substances to a high temperature, sufficient to deprive them of their moisture and volatile matter. When intended for chemical uses, charcoal is made by exposing wood to heat, in iron cylinders, or other close vessels. It is also manufactured in kilns, built for the purpose. But, for the common purposes of fuel, it is made by a sort of smothered combustion, in which masses of wood, when set on fire, are covered with earth, so as nearly to exclude the atmospheric air. This exclusion of air prevents the wood from being consumed, while the red heat,

which is kept up for some time, dissipates the moisture from its pores. Charcoal is generated in a small way, every night, in fires which are raked up ; the brands, and half-burnt coals, are kept from consuming, by the partial exclusion of the air, while the light ashes, being a slow conductor of caloric, prevent them from cooling below a red heat. Charcoal, when newly made from the heavier kinds of wood, such as oak and walnut, is a powerful, and, for some purposes, an economical kind of fuel. Coke, a kind of fuel, used for certain purposes in England, and this country, is charred pitcoal. It produces a strong and steady heat, but does not blaze. Large quantities of coke are formed in the manufactories of coal gas. A kind of charcoal, said to be of superior quality, has been manufactured in France, from peat.

COMMUNICATION OF HEAT.

Radiated and conducted Heat.—Caloric, or heat, is communicated to apartments, by fires kept in them, in two ways. A part of it is radiated, the rest is conducted. The first portion passes through the air with great velocity, in diverging rays. The second penetrates slowly through the densest bodies, whether transparent, or opaque. In a fireplace, or open stove, the heat, which is felt by holding the hand before the fire, is radiated caloric. That which is felt by placing the hand on the iron, or bricks, is conducted caloric. To enjoy the full effect of radiated caloric, we must be in presence, or sight, of the radiating object. To receive conducted heat, we must be in contact with the substance which imparts it. Since, however, we cannot remain in contact with the fire itself, we derive our conducted heat from the air, a fluid, which constantly touches, and envelopes our persons ; and which, when heated, in itself becomes a source of warmth to us. The object of the various contrivances, known under the names of stoves and fireplaces, is to enable us to use fire with safety, and to obtain from it a due supply of radiated caloric, and heated air.

In common cases, radiant heat is more agreeable than conducted heat, when we wish to obtain a sudden warmth ;

since its degree may be increased at pleasure, by altering our proximity to the fire; the effect of the radiation being inversely proportionate to the square of the distance. But, as only one half of the recipient body can be warmed at a time, by radiation, no person, surrounded by a cold atmosphere, can be made uniformly warm, by the radiated heat of a fire. It is only when the surrounding atmospheric air has become warm, and a counter radiation is produced from other objects, that we obtain all the advantage which fire is capable of affording.

Fire in the open Air.—The simplest, and least effectual, mode by which heat can be obtained, is from a fire in the open air. The hunter, or backwoodsman, when he encamps for the night, builds a fire of logs, and lays down to sleep, with his feet extended towards it. In this situation, he can enjoy only a small portion of the radiated heat of the fire, this heat being thrown off equally in all other directions. Of the conducted heat, he obtains none; for the air which surrounds the fire, having nothing to confine it, ascends, by its diminished specific gravity, as fast as it is warmed, and its place is immediately supplied by strata of colder air from beneath. Hence, a current of cold air will take place, from the atmosphere, on all sides, towards the fire, so that the person who derives warmth from the fire, on one side, will on the other be exposed to additional cold. The first step towards remedying this inconvenience, is, to build up a barrier, or imperfect wall, on the outside of the place occupied by the tenant. This will intercept the current of cold air, and oblige it to approach the fire by other directions, at the same time that it will gradually become heated itself, and radiate back a portion of its warmth. The next improvement consists in extending the wall, so as completely to surround the fire, thus obliging the air to approach it from above, or from doors and avenues purposely left for its entrance. This is, in fact, the commencement of a dwellinghouse. A roof, with an aperture for the escape of the smoke, is a further improvement on the plan, and, lastly, the introduction of a chimney, at once renders the mansion convenient and tenantable.

Fireplaces.—Chimneys, from their usual situation in regard to rooms, and also for the sake of a more perfect draught, have an opening on one side of their base, to which we give the name of fireplace. The fireplace, in former times, was an oblong, or cubical, cavity, having its sides nearly at right angles with the back. In a cavity of this description, the greater part of the heat, generated by the fire, was totally lost to the apartment, nearly all the conducted heat being carried, with the air, up the chimney; while, of the radiated heat, but a small part could directly enter the room, viz., the part radiated from the front of the fire; the heat of the other sides being chiefly thrown into the hearth, back, and sides, or up the chimney. In the old fireplaces, the inconvenience was still further augmented, by increasing their dimensions to an enormous size, so that seats or benches could be placed on each side, on the inside of the jambs. The consequence was, that a prodigious current of air was constantly carried up the chimney, and the seats, on the inside of the fireplace, became the only comfortable ones in the room.

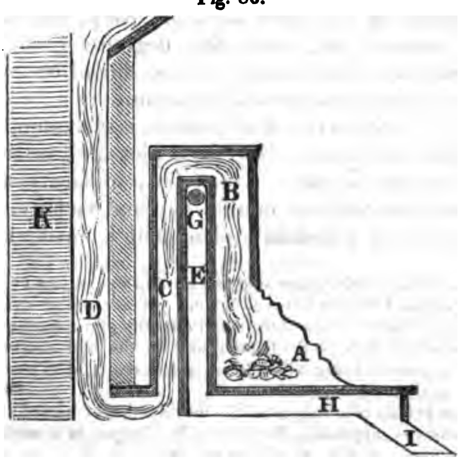
Admission of Cold Air.—It is obvious, that in apartments with open fireplaces, the air must be continually shifting, and that cold air must enter at the crevices of the doors and windows, to supply the place of that which maintains the combustion, or escapes up the chimney. In moderate weather, this change of air is an advantage, since it freshens and ventilates the room, the air of which would otherwise become close and impure. In moderate weather, also, the radiant heat is adequate to warm the walls of the room, which, in their turn, become sources of radiant heat, and likewise contribute to warm the air by their contact. But, in very cold weather, it is difficult to render a large apartment warm by means of a common open fireplace; for, in proportion to the briskness of the fire itself, will be the rapidity with which the cold air presses into the room, and a person near the hearth feels, perhaps, as much cold on one side of his body, as heat on the other.

Open Fires.—The cheerful sight of an open fire, to

which habit and association have attached us, has created a strong, and almost general, preference for the open fireplace, over the close stove, and a desire, by remedying its defects, to make it more effectual and useful. Of various philosophers who have exercised their ingenuity on this subject, the two who appear to have labored with most success, are our countrymen, Dr. Franklin, and Count Rumford.

Franklin Stove.—Dr. Franklin, whose writings on the economy of fire contain the basis of many of the improvements which have since been introduced, invented an apparatus of cast-iron, to which he gave the name of the *Pennsylvania Fireplace*, but which is now often known by the name of *Franklin Stove.* This fireplace, when executed agreeably to the author's instructions, is one of the most effective and economical modes in which an open fire can be managed. By means of a narrow and circuitous smoke-flue, which is surrounded and intersected with air passages, a great part of the heat of the fire is retained in the room, and, at the same time, a current of fresh air, warmed by the fireplace, is introduced into the apartment. In Fig. 86, is seen a section of the Pennsyl-

Fig. 86.



vania fireplace. A, is the place of the fuel and fire; BCD, the smoke flue, passing, first upward, then downward to the floor, and escaping by the chimney, D, next the wall, K. EH, is the air chamber, into which the air is admitted from without the house, through the passage, I. After being heated, it is discharged into the apartment by lateral openings at the top, G.*

Fireplaces which stand out into the room, and fireplaces with hollow backs, or pipes for hot air, are to be viewed, in most instances, as simplifications only, of Franklin's plan.

Rumford Fireplace.—Count Rumford's fireplace forms a pleasant and effectual mode of economizing the heat of an open fire; besides which, its cheapness and simplicity give it the advantage over more complicated plans, and have occasioned its very general introduction. The peculiarities of this fireplace consist, 1st, in an advanced back, which brings the fire nearer into the room, and, at the same time, by narrowing the throat of the chimney, diminishes the current of air which escapes through it; 2dly, in the oblique sides, or covings, of the fireplace, which are enabled, when heated, to radiate their warmth into the room. Count Rumford recommends that the angle, made by the sides with the back, should be one of one hundred and thirty-five degrees. He also advises that the color of the covings should be white, this color being best adapted for radiation.

Double Fireplace.—For parlors, and common apartments, no contrivance appears so pleasant and effectual, as the double fireplace, which has, of late years, been extensively introduced in this city and vicinity. It is a modification of Franklin's plan, and is made from any

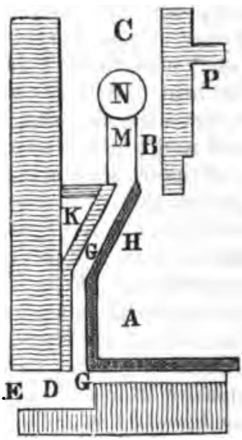
* Most of the articles, now sold as Franklin stoves, are very different from the original Pennsylvania fireplace. If any defect existed in the plan of the inventor, it was in the small quantity of air admitted through a circuitous and obstructed channel, and in the bad character of the material, cast-iron being liable to warp and crack, if exposed to great heat and cold on opposite sides.

The first person who suggested the introduction of heated air, through hollow passages, appears to have been M. Gauger, in a work, entitled, *La Mechanique de Feu*, published in 1709.

common fireplace, by inserting within it another fireplace, made of soapstone, leaving an empty space, of about an inch in depth, between the two, so that, when finished, the back and sides may be hollow. This hollow space does not communicate with the fire, but has two openings, one at bottom, communicating with the external atmosphere by a perforation in the wall, or by a tin pipe laid in the floor; the other, opening into the apartment, at a point higher than the fireplace, and commonly at the side of the chimney. In this fireplace, an open fire, of wood or coal, may be used with the full advantage, ever obtained, of its radiant heat. A large part of the conducted heat is also saved, since the air, which enters from without, becomes heated in the hollow space, and ascends by it, in consequence of its diminished specific gravity, entering the room in a strong warm current. This air serves the purpose of ventilation; it supersedes the entrance of cold air through the crevices and keyholes, and is also a preventive against smoking. The circumstances to be attended to, in the construction, are as follows: 1. The openings for the air should be large, in common cases from four to seven inches in diameter, since it is better to introduce a large quantity of air, moderately warmed, than a small quantity made very hot. More heat will, in this case, be conducted from the stone, and the unpleasant effects of *burnt air* will be avoided. 2. The openings into the room should be made, when practicable, at least a foot higher than the top of the fireplace; for, when they are on a level with it, or lower, the warm air is liable to be drawn up the chimney, and the main object defeated. But, if the opening is above the fireplace, then the warm air will ascend, and be diffused through the upper parts of the room, till the whole is gradually warmed. 3. The cold air should be taken from without the house, and not from an entry or cellar; because changing the air of those places, in Winter, is apt to reduce them to a freezing temperature. The external opening should be guarded with a wire net, to exclude leaves and light substances; and the internal, should be commanded by a shutter, to regulate the heat. For safety, it is best, though not always

necessary, that the hot air passage should not be in contact with the wood work of the house. 4. Good soapstone is the best material for these fireplaces, and, with careful use, will last many years. See *Soapstone*. For wood fires, the stone should be an inch and a half thick, and for coal fires, two or three inches.

Fig. 87.



In Fig. 87, is a section of a double fireplace. A, is the place of the fire; H, the soapstone back; B, the throat; C, the chimney; E, the external opening; DGG, the hollow, or passage, for heated air; M, a pipe for conveying the hot air to N, a lateral opening into the room; P, the mantel-piece. A soapstone fireplace may be rendered very effectual, by causing it to project a little into the room, and by adding an air box to the top, as seen in Figs. 88 and 89. In the section, Fig. 88, A, is the fire; B B, the smoke passage; C c c, the air passage; D, a box for heated air, covering the fireplace, and communicating with the hollow back c c, by a side passage, at the dotted lines; E, a side opening for discharging the hot air into the room; G, the mantel-piece. In fireplaces of cheap construction, a simple, hollow back, made by one

Fig. 88.

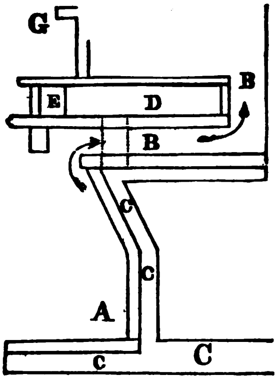


Fig. 89.

slab of soapstone, with openings, as have been described, will contribute much to increase the warmth of the room.

Coal Grate.—When coals are used for fuel, it is necessary, on account of their small size, to confine them together with a grate. As they contain more combustible matter, in the same space, than wood, and produce a greater degree of heat, a much smaller fireplace answers for them. A very small throat, also, in the chimney, is sufficient to carry off the smoke from a common coal grate. With this exception, it has the same characteristics as a common fireplace.

Anthracite Grate.—Grates for burning anthracite, require more perpendicular height than others, and should be of such a proportionate depth, as will keep the coal together, and not offer too great a surface to the atmosphere. In extremely cold weather, it is observed, that the front surface of anthracite grows black, and burns feebly, in an open grate, while it does not in a furnace or stove. In this case, the cold air conducts off the heat of the surface faster than the combustion renews it; and, if the amount of surface be too great, in proportion, for that of the solid contents, the fire will go out. Anthracite grates are usually provided with a very narrow throat, to carry off the gases, which result from the combustion; there being no visible smoke. The throat, however, should always be large enough to transmit the smoke of any other fuel; for otherwise, a part of the carbonic acid which is formed, will escape into the room, and contaminate the atmosphere, in the same way as burning charcoal. See chapter II. article *Anthracite.*

Burns's Grate.—Mr. Burns, of Glasgow, has made an alteration in the coal grate, by introducing the external air through an opening immediately under the grate. This air supplies the fuel with oxygen, and furnishes most of the current which passes up the chimney. The air of the room, of course, remains comparatively stationary, and is sooner heated. This plan, when combined with the double fireplace, already mentioned, is a powerful mode of obtaining heat. A movable stone screen may be placed in front of the ash pit, to prevent the ashes from being blown into the room. The external opening which admits the air, should not be near any wood work, as sometimes the current is reversed by winds, and sparks and smoke are driven out at the opening.

Building a Fire.—In building and maintaining an open fire, whether of wood or coal, certain circumstances deserve attention, in the common fireplaces. It is advantageous, to make the perpendicular height of the fuel as great, as is consistent with safety. A stratum of coals, or ignited wood, will radiate more heat into the lower part of the room, if placed vertically, than if laid horizontally.

Fuel, for economy, should be so subdivided, as to be easy of ignition, and so placed, as to give free access for the air to its different surfaces. In this way, the smoke is more likely to be burnt. To secure the greatest effect of radiation, the combustion should be kept, as much as possible, to the front surface. In kindling a fire, the live coals should be kept together, and placed near the bottom. A blower, added to a common grate, converts it, for the time being, into a wind furnace.

Furnaces.—The object of the furnaces, used by artists and manufacturers, is the reverse of that intended to be produced by stoves and fireplaces; furnaces being required to produce an intense heat, and to confine it to a limited space. Hence, furnaces and their chimneys are surrounded with non-conductors, that they may expend as little of their heat as possible, on the air and surrounding objects. They are commonly made of fire-proof bricks, and, when small, are enclosed in iron. Their most simple form is that of an upright, hollow cylinder, with a grate at bottom. *Air*, or *wind*, *furnaces*, have their combustion supported by a draught of air, which ascends rapidly, because it is strongly heated and rarefied. *Blast furnaces* have the air driven through their fuel with bellows. *Reverberating furnaces* are provided with a concave covering, which reverberates, or throws back the flame, upon the substances to be heated or melted. There are some cases, in which furnaces are used for warming dwellinghouses, particularly when fuel is used which requires strong ignition, such as the anthracites.

Stoves.—Stoves differ from fireplaces, by enclosing the fire, so as to exclude it from sight, the heat being given out through the material of which the stove is composed. The common Holland stove, of which we have an almost infinite variety of modifications, is an iron box, of an oblong square form, intended to stand in the middle of a room. The air is admitted to the fire through a small opening in the door, and the smoke passes off through a narrow funnel. The advantages of this stove, are—1. That, being insulated, and detached from the walls of the room, a greater part of the heat, produced by the combus-

tion, is saved. The radiated heat being thrown into the walls of the stove, they become hot, and, in their turn, radiate heat on all sides to the room. The conducted heat is also received by successive portions of the air of the room, which pass in contact with the stove. 2. The air being made, as in furnaces, to pass through the fuel, a very small supply is sufficient to keep up the combustion, so that little need be taken out of the room. 3. The smoke, being confined by the cavity of the stove, cannot easily escape into the room, and may be made to pass off by a small funnel, which, if sufficiently thin and circuitous, may cause the smoke to part with a great portion of its heat, before it leaves the apartment. These circumstances render the Holland stove one of the most powerful means we can employ, for keeping up a regular and effectual heat, with a small expense of fuel.

The disadvantages of these stoves are, that houses containing them are never well ventilated, but that the same air remains stagnant in a room, for a great length of time. Hence, it necessarily becomes impure, by the breath of persons who remain in it, and by the burning of dust, and other substances, which settle on the heated iron of the stove. A dryness of the air is also produced, which is oppressive to most persons, so that it often becomes necessary to place an open vessel of water on the stove, the evaporation of which may supply moisture to the atmosphere. Where rooms are kept very warm by stoves, it is found advantageous, even, to cause the water to boil, in order to insure a sufficient supply of vapor. Stoves are very useful in large rooms, which are frequented occasionally, but not inhabited constantly; as halls, churches, &c. But, for common rooms, which are occupied at all times, they are objectionable, for the reasons which have been stated.

Russian Stove.—In cold countries, where it is desirable to obtain a comfortable warmth, even at the sacrifice of other conveniences, various modifications of the common stoves have been introduced, to render them more powerful, and their heat more effectual. The Swedish and Russian stoves are small furnaces, with a very cir-

cuitous smoke-flue. In principle, they resemble a common stove, with a funnel bent round and round, until it has performed a great number of turns, or revolutions, before it enters the chimney. It differs, however, in being wholly enclosed in a large box of stone, or brick work, which is intersected with air pipes. In operation, it communicates heat more slowly, being longer in becoming hot, and also slower in becoming cold, than the common stove. Russian stoves are usually provided with a damper, or valve, at top, which is used to close the funnel, or passage, when the smoke has ceased to ascend. Its operation, however, is highly pernicious; since burning coals, when they have ceased to smoke, always give out carbonic acid in large quantities, which, if it does not escape up the chimney, must deteriorate the air of the apartment, and render it unsafe.

Cockle.—The name of cockle is given to an upper part of a stove, or furnace, resembling an inverted vessel. A large cockle saves much heat, since its extensive surface conveys the heat from the flame and smoke, and communicates it to the atmosphere. In some stoves, the cockle is filled with a checker-work of bricks, among which the smoke and flame circulate. After becoming once heated, these bricks are slow in cooling, and continue to yield warmth to the apartment, like the Russian stoves, for some time after the fire is extinguished.

Thermometer Stove.—Dr. Arnott's thermometer stove is a contrivance, for keeping up a uniform temperature, by an apparatus which regulates its own combustion, increasing or diminishing the draught, as the temperature falls or rises. It consists of an interior stove, or fire-pot, for burning anthracite coal, lined with fire-brick, and provided with the usual appendages of a door, grate, ash-pit, and pipe, or smoke-flue. Outside of this fire-pot, is placed a much larger box of sheet iron, in which the smoke, or rather the hot gas, from the anthracite, is made to circulate, by means of internal screens or partitions, until it is at length discharged into the chimney, thus keeping the surface of the outer box equally heated, in all parts. But the peculiar characteristic of this stove consists in a

self-regulating door, or valve, which admits the air to support the combustion, and which shuts, when the heat increases, and opens when it diminishes, so that the quantity of air admitted shall be such as to sustain always a uniform temperature. This air regulator is constructed on the principle, that all bodies expand by heat, and it may be contrived in a variety of ways. Bars, compounded of metals, having a different expansibility, have been made, to open and shut valves, as the heat and expansion increase or diminish. Out of many contrivances, Dr. Arnott appears to prefer some form of an inverted syphon, containing mercury, with a column of air inclosed in one of its legs. When the air expands or contracts, it moves the column of mercury, carrying with it a float, which raises or depresses the valve commanding the door.

The air regulator appears useful in remedying the evil, to which small anthracite stoves are liable, of burning out the coal too rapidly, and overheating the room at some times, while they are deficient in heat at others. Some objection would seem to exist against the employment of mercury in the regulator, on account of the deleterious fumes which may arise from that metal, when heated. But no practical inconvenience appears to have been noticed in Dr. Arnott's work. In regard to its heating power, it may be doubted whether this stove is adequate to counteract the cold of an American Winter, in the Northern States.

Carrying Heat.—Besides the methods, already mentioned, by which rooms are warmed by the radiation and communication of heat, from fires kept in the rooms themselves; another method has been used, in various buildings, by which fires, burning in one room, or part of the building, may warm other rooms, at a distance. This is done by communicating the heat to some movable vehicle, which afterwards carries it to different parts of the building, and expends it where it is wanted. The vehicles employed for this purpose are currents of air, water, and steam.

Heating by Air Flues.—Such is the tendency of heated, or rarefied, air to ascend, that buildings may be effectually warmed by air flues, communicating with stoves

in the cellar, or any part of the building below that to be warmed. A large suite of apartments may be sufficiently heated, in this way, by a single stove. The stove, for this purpose, should be large, and of a kind best adapted to communicate heat. It should be entirely enclosed in a detached brick chamber, the wall of which should be double, that it may be a better non-conductor, and prevent waste of the heat. The space between the brick chamber and stove, should not exceed an inch. In the apparatus of the Derbyshire and Wakefield Infirmaries, which has been imitated in this country, the whole of the air is repeatedly conducted, by numerous pipes, within half an inch of the stove and its cockle. For the supply of fuel, the same door which opens into the chamber, should open also into the stove, that there may never be any communication with the air of the cellar. A current of external air should be brought down by a separate passage, and delivered under the stove. A part of this air is admitted, to supply the combustion; the rest passes upward, in the cavity between the hot stove and the wall of the brick chamber, and, after becoming thoroughly heated, is conducted through passages in which its levity causes it to ascend, and be delivered into any apartment of the house. Different branches being established from the main pipe, and commanded by valves or shutters, the hot air can be distributed at pleasure, to any one or more rooms at a time. This plan is very useful in large buildings, such as manufactories, hospitals, &c., on account of the facility with which the same stove may be made to warm the whole, or any part of them. The advantage of a long, vertical, draught, enables us to establish a more forcible current of warm air. The rooms, while they are heated, are also tolerably ventilated; for the air, which is continually brought in by the warm pipes, displaces that which was previously in the room, which blows out at the crevices and keyholes, instead of blowing in, as it does in rooms with common fireplaces. Nevertheless, the warmth obtained from heated air alone, has some disadvantages, when compared with radiant heat, as is stated in the *general remarks*, at the end of this chapter.

Heating by Water.—Rooms may be warmed by causing a current of hot water to circulate through them, in tubes of various forms, giving out its heat as it proceeds. If we suppose a tight tube, of a circular form, to be filled with water, and placed upright, it may represent the simplest form of this apparatus. If a fire be applied to one side of this tube, the water in that side will become gradually heated, and, being thus rendered specifically lighter than the rest of the water, it will ascend, causing the water of the opposite side to descend, until it comes, in its turn, to be heated by the fire. Thus a continued current will be kept up, and heat given out from the most distant parts of the tube. By varying the application of this principle, hot water has been made to warm manufactories, dwellinghouses, and conservatories. But, when much heat is required, the apparatus becomes large and expensive; and, if negligently attended in Winter, the water is liable to freeze, and burst the tubes.

Another mode has been introduced by Mr. Perkins, of heating by water under a high pressure. In this mode, the water is confined in strong iron tubes, not exceeding an inch or two in diameter, and variously convoluted, so as to afford the requisite amount of surface, for giving off the heat. The water is raised to a higher temperature than the boiling point, the strength of the tubes counteracting its explosive tendency. It thus gives off more heat than water, at temperatures below this point; but its use requires caution.

Heating by Steam.—Steam is found to be a useful medium for communicating heat to large buildings. It has the advantage, that it conveys heat in any direction, horizontally, upward, or downward, and to the most remote apartments of the largest buildings. In greenhouses, it has been made to yield a sufficient supply of heat, at the distance of eight hundred feet from the boiler in which it is produced. When steam of low pressure is employed, the heat never exceeds two hundred and twelve degrees, Fahrenheit, so that the air, in contact with the apparatus, is never contaminated by the burning of dust.

In constructions for heating by steam, a strong boiler

is made use of, provided with a safety-valve, and the other appendages common to the boilers of steam-engines. From this boiler, a steam-pipe is carried in any required direction, and distributes branches to the different apartments which are to be warmed. Whenever the water in the boiler is heated to the point of ebullition, steam passes into the pipes, and drives out the atmospheric air through valves, provided for the purpose. As long as the surface of the pipes remains of a less heat than two hundred and twelve degrees, a part of the steam continually condenses, and is immediately succeeded by fresh steam from the boiler. In the act of condensing, it gives out its latent heat to the material of which the pipe is made, and this material, in turn, imparts it to the air of the room. In this manner, the steam will continue to be condensed, and to give out heat, as long as the air of the room is at any point, below two hundred and twelve degrees. By the condensation, a quantity of water is constantly formed, which, for economy of heat, is returned by a separate pipe, while it is yet warm, to the boiler. Inverted syphons, containing water, are used, to prevent the air and steam from communicating. If the steam pipes are made of thin, or weak materials, it is necessary to provide them with safety valves, opening inward; otherwise, they would be crushed, by the pressure of the atmosphere, when the fire is extinguished.

In calculating the effect of this method, it has been ascertained, that, under favorable circumstances, one cubic foot of boiler will heat about two thousand cubic feet of space, in a cotton-mill, where the required temperature is from seventy to eighty degrees of Fahrenheit.* And, if we allow twenty-five cubic feet of a boiler for one horse's power, in a steam-engine supplied by it, it will follow, that such a boiler is adequate to warm fifty thousand cubic feet of space, for every horse's power. It is said, also, that every square foot of surface, in a steam-pipe, will warm two hundred cubic feet of space. These calculations, however, do not apply to buildings unfavorably arranged,

* Buchanan, on Heat and Fuel, p. 160.

nor to very cold weather. The pipes, employed to distribute the steam, should be made of materials which cool most rapidly. Iron, of which the surface is tarnished with rust, is found to exceed tinned iron, in the rapidity of cooling, in the proportion of about eighteen to ten.* Room must be allowed for the expansion of the pipes, which, in cast-iron, may be taken at a tenth of an inch for every ten feet in length. In cotton and calico manufactories, steam is found very advantageous in drying cloths quickly, and well.

In comparing the effect of steam heat, with that of smoke-flues, different representations have been made by writers on the subject. Mr. Tredgold observes, that "he must be a novice in the science of heat, who cannot produce nearly the same effect by the one as by the other, all other circumstances being the same." The steam-apparatus, however, requires more careful management, and does not admit of neglect. Although easily kept in order, by a skilful attendant, yet it cannot, in common cases, be intrusted to ordinary or careless persons.

RETENTION OF HEAT.

Causes of Loss.—However advantageously heat may be produced and distributed, it will fail in producing its desired effect, unless suitable provision is made for retaining it, where it is wanted. Heat constantly tends to an equilibrium; and, unless this tendency be retarded, dwellinghouses and their apartments will cool, as fast as they are warmed. The chief causes which operate to cool apartments, are—1. The escape of the warm air upward, through crevices, apertures, and chimneys. 2. The power of conducting and of radiating heat, which all substances possess, in a greater or less degree, and by which the internal heat of houses is gradually conveyed to the external atmosphere. To obviate the first of these causes, apartments should be made as tight as possible; and to prevent the second, at least in part, their walls should be made thick, and of materials which are slow conductors of heat.

* Tredgold, p. 68.

Crevices.—As crevices in rooms commonly occur from the shrinking of their materials, care should be taken to employ, in building, wood which is thoroughly seasoned, and which is known to be permanent in its dimensions. Of the kinds of wood employed for doors and windows, mahogany is the most permanent, and next to this, is cherry-tree, and pine. Oak, and some other hard woods, are very liable to shrink, and crack.

Chimneys.—Chimneys occasion less expenditure of warm air from rooms, than their size would lead us to expect, because they open at the bottom, or near the floor. If, therefore, the room be tight, and the chimney cold, the warm air, while at rest, will be retained in the upper portion of the room, or that which is above the fireplace, as effectually as in a gasometer. But if a chimney is heated, and a current thus established through it, it may then drain off the air of the apartment; and hence the foundation for the common belief, that a room becomes colder in the night, for having had a fire in the day. The warm air may be retained, if the throat of the fireplace be closed with a damper.

Entries and Skylights.—Entries, as they are commonly constructed, extending from the bottom of a house, to the top, have a bad influence on the retention of heat. The evil is increased, when they are surmounted with a skylight, the panes of which are arranged like tiles, and not air tight. Such entries are difficult to warm, and serve to drain off the warm air of apartments, whenever the communicating doors are left open; and to transmit it to the roof.* To prevent this effect, entries should be commanded with doors in different stories; and skylights should be made sufficiently erect, to have their sashes complete, or else a tight, horizontal window should be added, underneath the skylight.

Windows.—The heat conducted off by the external atmosphere, passes, most readily, through the windows,

* The opposite currents, in an open door, by which cold air enters at bottom, and warm air escapes at top, may be made obvious, in the familiar experiment of holding a lighted candle at the bottom and top of the door. In one case, the flame will point into the room, and in the other, out of it.

since the walls of houses, especially when thick, are slow in conducting caloric, while a pane of glass interposes but a slight barrier against its escape. On this account, the unnecessary multiplication of windows should be avoided. In cold climates, a great advantage is obtained from using double windows in winter, which, by confining between them a stratum of air, interpose a powerful non-conductor between the room and the atmosphere. To secure the full benefit of the double window, it should be made sufficiently tight, so that the included stratum of air may not easily change; otherwise, the expected benefit will not be obtained. It should not, however, be hermetically tight, for, in that case, the glass may become opaque in Winter, by the condensation of moisture.

VENTILATION.

Objects.—If the only object of human habitations were to procure heat, it would be best obtained by keeping the air in a state of stagnation, and employing those means to create warmth, which are attended with the least circulation, or change. But, since the air of inhabited rooms would become, in time, unfit for respiration, it is necessary that it should be removed, as fast as deteriorated, and be replaced by fresh air from abroad.

Modes.—Rooms which are heated with stoves, are never well ventilated. Those heated by common fireplaces, are ventilated, at the expense of losing much of their warmth by the admission of cold air. Those heated by the double fireplace, [p. 310,] are sufficiently ventilated, with air at an agreeable temperature. Rooms heated by steam, or by hot water, are not at all ventilated, unless it be by additional arrangements. Those warmed by hot-air flues are apparently well ventilated; yet, in hospitals, and crowded buildings, it is sometimes necessary to add fire-places, or other openings, for discharging the air.

Ventilators.—The principal gases, which it is the object of ventilation to remove, are carbonic acid, and nitrogen; these being produced in excess, by the process of respiration, by the combustion of lamps, and by fires with an imperfect draught. The specific gravity of carbonic

acid is greater than that of common air. That of nitrogen is somewhat less. These gases, when evolved, are at a higher temperature than the surrounding air, and are mixed with steam; therefore, while rarefied by heat, they ascend to the top of the apartment. On this account, the *ventilators* intended to discharge them, are made to consist of openings, commanded by shutters, at the upper part of the room. In rooms which are liable to be crowded with people, these ventilators have a good effect, especially in warm weather, and the larger they are, the greater is the advantage derived from them. In cold weather, however, they have the disadvantage, that they discharge the pure heated air, in common with the noxious vapors, and thus defeat our efforts to obtain warmth. In common dwellinghouses, no more ventilation is necessary, than can be obtained from doors, open fireplaces, and windows, which open at top, as well as at bottom.

An ingenious and effectual mode of ventilation has been introduced in the House of Commons in London, by Professor Reid. The fresh air, before entering the house, is warmed, by passing between flat tubes of iron, filled with hot water. From a place of these, in a vault below, it spreads under the floor, and enters the room from a vast number of small openings in the floor. It then passes upward, carrying with it the impure gases of the room, and escapes, through openings made for the purpose in the ceiling. From these, it is collected, and carried downward, in a suitable flue, till it arrives under the grate, where it is used to feed the fire. A regular and agreeable change of air is thus kept up, sufficient, it is said, to render imperceptible in a few minutes, the vapor of ether, or of fired gunpowder. Some inconvenience has been experienced from the raising of dust, introduced on the feet of the occupants; but this, as Dr. Arnott suggests, might be remedied, by making the air enter a little above the floor, or carpet.

Dr. Ure recommends the ventilation of crowded rooms by mechanical means. A fan ventilator, made to revolve by a steam-engine, produces an effect thirty-eight times greater, than can be obtained by the consump-

tion of the same fuel, in the ordinary mode of chimney ventilation.

Culverts.—In the Derbyshire Infirmary, an ingenious mode of ventilation is adopted, by means of an empty culvert, or subterranean passage ; one end of which opens into the building, while the other end is provided with a turncap, presenting its open mouth to the wind. The air, in passing this culvert, partakes of the temperature of the earth, and is thus warmed in Winter, and cooled in Summer. The effect, however, is obviously of a limited kind, since the continual transmission of air must bring the surface of the culvert to a temperature, approaching that of the surface of the ground.

Smoky Rooms.—Under the head of ventilation, may be placed the art of remedying smoky apartments. Smoke is a heterogeneous vapor, composed of the gases which result from combustion, together with a quantity of opaque matter, which escapes from the fuel without being burnt. Smoke is specifically heavier than the atmosphere, and always descends, after it is cooled, as may be seen by observing the current of smoke from a chimney, in a cold morning. At the time, however, of its disengagement from the fire, it is rarefied by heat, and will always ascend through a chimney properly constructed, if it is not prevented by some opposing influence. The causes which produce smoky apartments are, principally, the following.

Damp Chimneys.—When a fire is first made in a chimney, which has not been used for many months, it is apt to smoke. This is, because the chimney is cold, and the column of air which it contains is not lighter than the surrounding atmosphere. The difficulty of remedying this evil is greater, if the bricks have absorbed much moisture, or the chimney be new ; as, in this case, the chimney will not be well heated, till the moisture is evaporated. To expedite the drying and heating of the chimney, a window should be kept open on the side against which the wind blows, and the communication with the rest of the house, at the same time, closed. This will mechanically assist the smoke and hot air, in ascending the chimney.

Large Fireplaces.—If a fireplace be made too high,

it will be liable to smoke; for, since the throat of the chimney takes in air from all directions, if the fire be too remote from this point, its smoke will be less likely to find its proper way. On the other hand, the lower the mantel-piece is brought, the nearer will the fireplace approach to the character of a wind furnace. In like manner, if the throat of the fireplace be too large, the air of the room, as well as that of the fire, will pass freely up the chimney, and thus the whole included air being colder, its current will be more sluggish. The advanced back of the Rumford fireplace, by contracting the throat, remedies this difficulty; and, at the same time, presents a mechanical obstacle against sudden counter currents.

Close Rooms.—Closeness of a room is a cause of its being smoky. If the walls, doors, and windows, are air tight, or nearly so, the outer air cannot enter, to take the place of that which passes up the chimney. The current of heated air and smoke will, therefore, be interrupted, and expand into the room. In most rooms, it happens, that the crevices, occasioned by the shrinking of the wood, or by the want of exactness in finishing, admit air enough, and more than enough, to supply the chimney. In new apartments, however, where all the joinings have been made with great accuracy, it has been found necessary to make perforations in the walls, to admit air sufficient to keep up a current. These should always be made behind the back of the fireplace, when possible, for reasons already explained.

Contiguous Doors.—The doors of a room, if placed very near a fireplace, or on the same side of the room with it, are apt to occasion a smoke, as often as they are opened. The gust of air, which enters at an open door, so situated, blows across the chimney. A part of it ascends the flue, while the rest extends into the room, carrying with it a part of the smoke.

Short Chimneys.—The longer a chimney is, the more perfect is its draught, since the upward tendency is proportionate to the difference of weight, between the column of air included in the chimney, and a similar column of external air. Short chimneys, or flues, are liable to smoke,

from the heated passage not being long enough to establish a strong current. The fireplaces in upper stories are more apt to smoke, than those in the lower apartments. In low houses, outhouses, &c., the chimney should always be carried to the greatest practicable height. Two flues, in the same chimney, or stack, should not communicate at any point, short of the top.

Opposite Fireplaces.—When two chimneys exist in different parts of the same room, or in rooms which communicate by doors, it is difficult to kindle a fire in one, while the other is burning, especially if the room be tight; because, in this case, the fire, which is first established, feeds itself by a current brought down the vacant chimney. After both fires are kindled, it is necessary to keep up a certain equilibrium between them, otherwise, the stronger will overpower the latter, and draw down its smoke into the room. If doors or windows be opened, the evil is obviated. If the fires are in different rooms, the communicating doors between them should be shut.

Neighboring Eminences.—The vicinity of elevated objects, such as hills, precipices, or very high buildings, is productive of smoky rooms to houses in their neighborhood. When the wind blows in a direction from the elevated object to the house, it falls down, in an oblique direction, upon the roof; a part of it enters the chimney, and beats down the smoke, by overpowering its current. On the other hand, when the wind sets towards the hill, or elevated object, its passage becomes obstructed, and it presses in every direction to escape; and while its upper portions pass off by the top of the opposing body, the lower portions press downward, through any passages which may afford them an escape. Chimneys, in houses thus situated, should be carried up to a great height, so as, if possible, to overtop the eminence, their sides being secured by iron braces.

Turncap, &c.—In many instances, a turncap, which is a curved tube, regulated by a weathercock, so as always to turn its mouth in a direction from the wind, will prevent smoking, in the case last stated. The turncap offers, also, a security against the influence of strong winds,

which, in common cases, and in houses most favorably situated, often invert the course of the smoke, by the strong pressure they exert on the tops of chimneys, and by impinging against their inner side. In like manner, the *pots*, which are frusta of cones, or pyramids, placed on the tops of chimneys, assist the escape of smoke, by causing the wind to glance upward from their sides.

Contiguous Flues.—When two chimneys are contiguous to each other, or in the same stack, one is frequently liable to smoke, when the other contains a fire, from a variety of circumstances. Not only the effect of high winds, but also any circumstance, which tends to produce an inverted current, may bring down the smoke from one chimney into the apartment which contains the other. To prevent this evil, the fireplaces should be furnished with dampers, which can be closed, when the flue is not in use.

Burning of Smoke.—This subject has excited great attention, owing to the nuisance produced by smoke, in large cities and manufacturing towns, chiefly where coal is burnt. In an economical view, it deserves attention, since it renders the same fuel more effective. Several methods of getting rid of smoke have been proposed, and executed with some success. The first mode is, to cause the smoke to pass through a portion of fuel which is perfectly ignited, and does not smoke, and which, if accurately managed, burns it up. This has been effected by an inverted draught, in a syphon chimney, and also by a revolving grate, which places the ignited fuel between the fresh fuel and the chimney. In a method of burning smoke, lately introduced by Messrs. Chanter and Gray, the form of the furnace, and position of the bars of the grate, are so arranged, that the fuel is regularly advanced, by gravitation, upon the inclined bars, without the aid of machinery, so that the inflammable gases are first set free, and being more charged with heat and oxygen, they are perfectly burnt, in passing over the fire. Another mode is, to mix a current of fresh air with the smoke, by tubes, or otherwise, which causes it to burn, upon passing in contact with a clear fire. A third method, which has been adopted for disposing of smoke, consists in building chim-

neys of an extraordinary height, so that most of the smoke may be deposited in soot, upon their sides. It has also been proposed to build circuitous chimneys, in one part of which the smoke should pursue a descending course; and that, in this part, a shower of water should be kept up, to precipitate the denser particles of the smoke. The expense of this method will probably prevent its use, unless, in some cases, to get rid of dangerous metallic fumes, in manufactories.

General Remarks.—Whatever be the methods adopted for the artificial warming of houses, two general considerations appear essential to the health and comfort of those who reside in them. These are, 1st, to maintain the purity of the atmosphere, and, 2dly, to keep in it an agreeable temperature. The first requires, that the air should be duly shifted by ventilation. The second requires, that a state of things should exist, in which the occupants should not be sensible of excess of heat, or cold. It is not, however, necessary for this purpose, that the atmosphere itself should always be heated to a temperate warmth. On the contrary, the faculties of healthy persons are more active in lower temperatures, and respiration is more satisfactory, because the volume of air inspired affords more oxygen. Generally, it is better to obtain heat, as far as practicable, from radiation and clothing, rather than from a hot atmosphere. An open fire, which sends off its rays of heat on one side, while they are reflected back from the opposite walls, will keep persons comfortable in a room, the air of which is ten or more degrees below the point which would be necessary, if the room were only warmed by a current of hot air, brought from a distant fire, the radiation of which is not available to the persons who require its benefit. It is probable, also, that a warmer clothing, than that commonly worn within doors, would be useful, in enabling persons to remain, with impunity and advantage, in moderately low temperatures. People, who are properly clothed and covered, ride with pleasure in cool weather, and sleep with health and comfort in cold chambers. On the other hand, a very warm atmosphere, whether produced artifi-

cially in Winter, or naturally in Summer, is always relaxing and debilitating, even under the lightest clothing. In hospitals, and sick chambers, it is found very difficult to render the warmth agreeable, at the same time, to those who are in bed, and to those who are sitting up, on account of their difference of covering. The practice, which has of late been gaining ground in this country, of keeping entries, and the sleeping chambers communicating with them, raised in Winter to a Summer heat, by means of stoves and cellar furnaces, cannot be regarded as otherwise than injurious. It produces the relaxing effect of warm weather, and renders the body tender, and more susceptible of the influence of cold, whenever it is exposed to the outer air.

WORKS OF REFERENCE.—FRANKLIN'S Works;—RUMFORD'S Works;—TREDGOLD, on Warming and Ventilating Buildings, 8vo. 1824; BUCHANAN, on the Economy of Fuel, and Management of Heat, 8vo. 1810; SYLVESTER'S Philosophy of Domestic Economy, and Account of the Derbyshire Infirmary, 4to.;—Account of the Wakefield Asylum, fol.;—FLOOD, on Warming Buildings by Hot Water, 8vo. 1837; — ARNOTT, on Warming and Ventilating 1838; — BRANDE'S Quarterly Journal, Nos. 22, 24, 27, 37, &c.

CHAPTER XIII.

ARTS OF ILLUMINATION.

Flame.—Support of Flame, Torches and Candles, Lamps, Reservoirs, Astral Lamp, Hydrostatic Lamps, Automaton Lamp, Mechanical Lamps, Pressure Lamp, Fountain Lamp, Argand Lamp, Submarine Lamp, Hydro-oxygen Light, Spirit Lamp, Reflectors, Hanging of Pictures, Transparency of Flame, Glass Shades, Sinumbral Lamp, Measurement of Light, Light Houses, Gas Lights, Coal Gas, Oil Gas, Gasmeter, Portable Gas Lights, Safety Lamp, Lamp without Flame, Modes of procuring Light.

Flame.—Artificial light is obtained, for common purposes, by the combustion of substances, which afford a permanent and luminous flame. All flames are not equally luminous. Those substances which, during combustion, produce chiefly gaseous, or volatile matter, emit

from their flame a very feeble light, as is seen in burning hydrogen, or sulphur. Those, on the other hand, which produce particles of solid matter during their combustion, yield a whiter flame, and a greater illumination. Sir Humphrey Davy is of opinion, that the brilliancy of the flames, used for illumination, is owing to the decomposition of the gaseous matter, towards the interior of the flame, by which solid charcoal is produced, and strongly ignited, before it is burnt. In a conical flame, like that of a candle, the combustion takes place most rapidly towards the surface, where the inflammable gas mixes with the atmospheric air. At the centre of the base, there is a darker portion, which consists of the matter, which is volatilized, but not yet fully on fire. In the interior, or most luminous part, the solid particles are brought to a white heat, just before they are burnt. The degree of their ignition is very powerful, since it is found, that the flame of a common candle is hot enough to melt a small filament of platinum.

Support of Flame.—That a flame may burn steadily, and produce a uniform light, it is necessary, that the supply of combustible matter should be constant and uniform. For this purpose, the combustible must be in a liquid, or gaseous state, when it approaches the flame, so that it may flow in an uninterrupted current. This current is commonly sustained, either by capillary attraction, or by mechanical pressure, operating on the reservoir which contains the combustible.

Torches and Candles.—The rudest material used for affording light, is the torch, composed of the resinous part of wood of the pine, or fir. In such torches, the turpentine, or melted resin, oozes out through the pores of the wood, and is gradually burnt, the wood interposing a vehicle, which regulates the supply, and prevents it from being consumed at once ; thus sustaining a dull and irregular light, with much smoke, for some time. A common candle is an improvement upon this natural mechanism. It consists, as is well known, of a fusible solid, as tallow, wax, or spermaceti, formed into a cylinder, having a wick of cotton, or some other porous substance,

for its axis. As the tallow melts by the radiated heat of the flame, it is carried upward by the capillary attraction of the wick, and is converted into vapor, as fast as it reaches the surface. The end of the wick, although it is blackened by the heat, is prevented from consuming, merely because it is surrounded by inflammable vapor, so that the oxygen of the atmosphere has no access to it. If the wick be turned to one side, so as to project from the blaze into the atmospheric air, it is immediately burnt off. Tallow, being more fusible than wax, requires to be burnt with a larger wick. The reason why this wick requires continual snuffing is, that, if it is suffered to become long, it divides the blaze, and intercepts a part of the light ; it also cools the flame, by its radiation, obstructs the combustion, and thus causes the escape of smoke, and the deposition of charcoal. Wax and spermaceti, being less fusible, may be burnt with a smaller wick, which, if made sufficiently slender, bends out of the flame, and burns off, so as not to require snuffing.

Lamps.—When the combustible used is fluid, at common temperatures, a vessel is necessary to contain this fluid, and supply it to the flame. In this country, and in England, whale oil is the principal fluid which is burnt in lamps.* In France, and the south of Europe, the oil of poppies, of nuts, rape seed, and the inferior kinds of olive oil, are used for this purpose. The volatile oils are but seldom burnt, since they exhale a strong odor, and throw off soot, during their combustion. They are also liable to take fire, over their whole surface, unless guarded with great care. Naphtha, however, as it is found native, or as it is distilled from pitcoal, is used for supplying street lamps, in some of the cities of Europe.

Reservoirs.—As the flame of a lamp is intended to consume no more oil, than is attracted upward by the ca-

* The oil which is extracted in cold weather, and called *Winter-strained oil*, remains fluid at low temperatures. The Summer-strained oil is liable to congeal in Winter. To obviate this inconvenience, lamps have been contrived for melting the Summer oil by the heat of the blaze. This is done, either by placing the reservoir of oil immediately over the blaze, or by conducting the heat by a metallic bar, which extends from the flame into the reservoir.

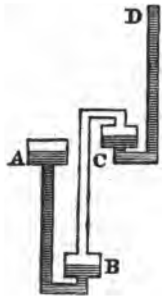
pillary action of the wick, it is necessary that a sufficient body of oil should be so placed, as to keep its surface, permanently, at a small distance below the level of the flame. The Greeks and Romans employed lamps of various forms, having the wick projecting from a sort of beak, at the side, nearly on a level with the surface of the oil. A similar plan is now practised in our street lamps. At the present day, portable lamps, of small size, are made with a central wick, having the reservoir of oil immediately below the flame. These reservoirs, if small, require frequent filling, and if large, cast an inconvenient shadow. All closed lamps require a minute hole, for the admission of air ; otherwise, the pressure of the atmosphere will prevent the oil from ascending the wick. If this hole be obstructed, the oil will also sometimes overflow, from the expansion of the confined air, when heated.

Astral Lamp.—With a view to get rid of the effect of shadow, various contrivances have been introduced, in which the reservoir is placed at a distance from the flame. In the astral and sinumbral lamps, the principle of which was invented by Count Rumford, the oil is contained in a large horizontal ring, having a burner at the centre, communicating with the ring by two or more tubes, placed like rays. The ring is placed a little below the level of the flame, and, from its large surface, affords a supply of oil for many hours. A small aperture is left, for the admission or escape of air, in the upper part of the ring. When these lamps overflow, it is usually because the ring is not kept perfectly horizontal, or else because the air hole is obstructed, a circumstance which may even happen from filling the lamp too high with oil.

Hydrostatic Lamps.—In several cases, the laws of hydrostatics have been applied to raise oil to the flame, from a reservoir, placed so far below the wick, as to be out of the reach of its effective capillary attraction. One of these hydrostatic lamps is constructed on the principle of Hero's fountain. It is composed of three vessels, or cavities, occupying different heights, and communicating by tubes, or syphons. One portion of oil, by descending gradually from the middle vessel, A, to the lower vessel,

B, causes another portion of oil to ascend from the upper vessel, C, to the flame, at D, the hydrostatic equilibrium being kept up by the intervention of the column of air, B C.

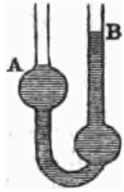
Fig. 90.



The lamps of Girard de Marselle, and of King, are on this principle, though the form of their apparatus is that of a cylinder, with internal tubes, opening into different cavities.

Other hydrostatic lamps are constructed, so as to contain, in one part, a column of some fluid, the specific gravity of which is considerably greater than that of oil; such, for example, as water saturated with salt. This fluid acts in such a manner as to raise the oil, by its greater weight. Thus, if an inverted syphon contain oil in one part, and salt water in another, the surfaces of the two fluids will stand at different heights, inversely pro-

Fig. 91.



portionate to their specific gravities. In the diagram, A, represents the surface of the heavier fluid, and B, that

of the oil. The bulbs serve as reservoirs, to prolong the action. Mr. Kiers' lamp is constructed on this principle. Those of Barton and Edelkrantz depend on the same principle ; but, in their construction, an open tube of oil is made to float in an upright vessel, containing a heavier fluid, which, in some cases, is salt water, in others, mercury. As the oil consumes, the tube, with the wick and light, descend in the supporting fluid, and follow the surface of the oil, as it lowers.

Automaton Lamp.—The automaton lamp of Porter, is a simple and effectual contrivance for keeping the surface of the oil near the level of the blaze. It consists of an oblong tin box, having the wick tubes at one end, this end being thus rendered heavier than the other. The box is suspended on pivots, placed a little out of the centre, and toward the tubes, so that, when the lamp is full of oil, the box will hang level. As the oil burns out, however, the end containing the tubes will preponderate, so as to keep the flame always near the surface of the oil. The annexed figures show the position of the lamp when full, and when half exhausted. This lamp is of cheap construction, and is said to be extensively used in cotton mills, and other manufactories, in the north of England.

Fig. 92.

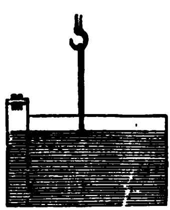
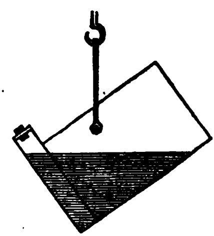


Fig. 93.



Mechanical Lamps.—Some lamps are manufactured in France, in which the oil is raised from a large reservoir below, to a small one near the flame, by means of a pump. This, in some instances, is worked by hand, and in others is carried by clock-work, the motion being de-

rived from a spring, which is wound up as often as necessary.

Pressure Lamp.—A lamp has been lately introduced from France, which represents a column, having the reservoir of oil in the pedestal. A piston, which is wound up at proper intervals, descends by a spring upon the surface of the oil, and forces out a continual stream, which ascends in a side passage to the level of the flame, where it escapes slowly, through a minute aperture. A part of it feeds the combustion, while the remainder overflows, and sinks back to the bottom of the lamp. These lamps are usually provided with long glasses. They consume much oil, and give a brilliant light. They are objectionable, on account of the frequent winding up, which is necessary, and on account of the liability of the small aperture, through which the oil is delivered, to become clogged with impurities, so as to cut off the supply, and cause the extinction of the lamp.

Fountain Lamp.—The most common mode of disposing of the oil, in large lamps, is to place the reservoir above the level of the flame, so that the burner, or part containing the wick, may be supplied in small quantities, as fast as its oil is consumed. These reservoirs are constructed on the principle of the bird fountain. They are open at bottom; but the oil is kept from running out at once, by the pressure of the atmosphere. The reservoir commonly terminates in a neck at bottom, with an opening on one side. This neck is immersed beyond the opening, in a small cavity, which contains oil nearly on a level with the burners, and communicates with them by tubes. So long as the whole of the opening is immersed, no oil can descend from the reservoir, because no air can enter, to take its place. But, whenever the oil in the lower cavity is consumed, so far as to sink below the upper edge of the opening, a bubble of air will enter the neck, and ascend into the reservoir; at the same time displacing an equal bulk of oil, which descends to feed the lamp. For convenience, the opening is commanded by a sliding valve; and, when the reservoir is to be filled, it is unscrewed from the lamp, inverted, and the oil pour-

ed in at the neck. When these lamps overflow, it is commonly owing to an increase in the heat of the room, which causes the air in the upper part of the reservoir to expand, and drive out a portion of oil. As it is not easy to prevent this occurrence, lamps are usually provided with receptacles at bottom, to receive the waste oil which runs over at the wick.

Argand Lamp.—This name is applied, after one of the inventors, to all lamps with hollow or circular wicks; and, of course, most of the lamps already described, may be also Argand lamps, if furnished with a circular burner. The intention of the Argand burner is, to furnish a more rapid supply of air to the flame, and to afford this air to the centre, as well as the outside, of the flame. It is constructed by forming a hollow cylindrical cavity, which receives oil from the main body of the lamp, and, at the same time, transmits air through its axis, or central hollow. In this cavity is placed a circular wick, attached at bottom to a movable ring. This ring is capable of being elevated, or depressed, by means of a rack and pinion, or, more commonly, by a screw; so that the height of the wick may be varied, to regulate the size of the flame. On the outside is placed a glass chimney, which is capable of transmitting a current of air, on the same principles as a common smoke-flue. When this lamp is lighted, the combustion is vivid, and the light intense, owing to the free and rapid supply of air. The flame does not waver, and the smoke is wholly consumed. The brilliancy of the light is still further increased, if the air be made to impinge laterally against the flame. This is done, either by contracting the glass chimney, near the blaze, so as to direct the air inwards, or by placing a metallic button over the blaze, so as to spread the internal current outward.

Submarine Lamp.—A lamp, ingeniously contrived to burn under water, has been connected with a diving apparatus, for examining the Thames tunnel. A box, containing the lamp, is made air-tight, with a glass in front, and a reflector behind. A quantity of alkali is placed in the box, and a reservoir of condensed oxygen is attached.

The oxygen is admitted in a small stream, to support the flame. The products of the combustion are water, and carbonic acid. The water is condensed, and the carbonic acid combines with the alkali, so that room is continually made for the fresh supply of oxygen.

A common lamp may be made to burn under water, by enclosing it in a lantern, through which a current of air is continually forced, by means of a pump, and an elastic pipe.

Hydro-oxygen Light.—If a stream of oxygen and hydrogen be directed, while in combustion, upon a mass of quicklime, the result is an intense degree of ignition, attended with a most brilliant light, which is said to be visible at a greater distance than any other artificial light. It has been modified, in various ways, by conducting a stream of oxygen through alcohol, or oil of turpentine, and by using it in the combustion of common oil.

Spirit Lamp.—It has been found, that certain volatile and inflammable liquids are capable of burning with a bright light, but are objectionable, on account of the generation of smoke and lampblack, during their combustion. This defect has been obviated, by burning them in combination with other fluids, and in a lamp of particular construction. Oil of turpentine, when mixed with a certain proportion of alcohol, and, perhaps, with other fluids, burns with a clear, white light, in a lamp properly constructed. As these liquids are cheaper than common sperm oil, lamps for burning them were at one time extensively introduced. But they were found objectionable, on account of the volatility and extreme inflammability of the liquid, by which serious accidents occurred, when it was spilt upon the dress, and took fire. A mixture, which appears to resemble the foregoing, in some respects, has been introduced under the name of "chemical oil," for the use of light houses. It gives an intense and brilliant light, much exceeding that of common oil.

Reflectors.—For obvious reasons, a lamp yields most available light, when it is placed in the centre of a room, or space, to be illuminated. In this situation, if a reflecting surface be brought near to it, this surface, by its re-

flection, will increase the amount of light in one direction, at the expense of intercepting it in another, so that the total advantage is not increased by the reflector. But, when a lamp is placed near a wall, so that a part of its rays are wasted, by falling immediately upon the wall,—in this case, if a polished surface be placed behind the flame, it reflects back most of the rays, which would otherwise be lost upon the non-reflecting wall; and thus it increases the effect of the light. The familiar fact, that rooms, with light-colored walls, are most easily lighted, is owing to the greater reflective power which such walls possess, when compared with darker surfaces.

Hanging of Pictures.—As the surface of varnished paintings has a considerable reflecting power, it happens, that when the spectator stands in the way of the reflected light, his eye is dazzled, and rendered incapable of distinctly perceiving the picture. Paintings, therefore, should not be hung opposite to lights, nor in any situation in which a line, drawn from the place intended for spectators, will make the same angle with the surface of the picture, as a line drawn from a window, or other illuminating point; the angle of reflection being always equal to the angle of incidence. As a general rule, a picture will be in a bad light, with regard to a spectator, whenever the image of a window could be seen by him in a looking-glass, occupying the same place as the picture.

Transparency of Flame.—If two lamps be placed by the side of each other, the flame of the one, when clear of smoke, does not intercept the light of the other, and casts little or no shadow. Count Rumford found, that the brilliancy of flame is, in some high ratio, proportionate to its elevation of temperature. If several concentric circular wicks, or several parallel flat wicks, be burnt near together, they produce more light, in consequence of the accumulation of heat, than they would do, if burnt separately.

Glass Shades.—To relieve the eye from the glare of light, produced by bright lamps, shades of roughened glass are frequently used. A rough surface upon glass may be produced by grinding it with sand or emery, by corroding

it with fluoric acid, or by covering it with powdered glass, and exposing it to heat, till the particles adhere. Glass shades have the effect to disperse the rays of light, by the numerous reflections and refractions which they occasion; till, at length, the light issues from all parts of their surface, and it appears as if the glass itself were the luminous body.

Sinumbral Lamp.—The reservoir of the sinumbral lamp is constructed on the same general principles with that of the astral. The ring, however, which holds the oil, is so formed, as to oppose the smallest diameter of its section to the rays of light. A large shade of ground glass is used, which nearly encloses the light, and, by the different refractions and reflections given to the rays, by the ground glass, they escape in all directions, so that there is no perceptible shadow, at a small distance from the ring. Reflectors are sometimes added, when it is desired to throw the principal mass of light in one direction.

Measurement of Light.—The following method of measuring the comparative illuminating power of different lights is founded on the law, that the amount of rays, thrown on a given surface, is inversely as the square of the distance of the illuminating body. Place two lights, which are to be compared with each other, at the distance of a few feet, or yards, from a screen of white paper, or a white wall. On holding a small card near the wall, two shadows will be projected on it, the darker one, by the interception of the brighter light, and the fainter shadow, by the interception of the duller light. Bring the fainter light nearer to the card, or remove the brighter light farther from it, till both shadows acquire the same intensity, which the eye can judge of with great precision, particularly from the conterminous shadows at the angles. Measure now the distances of the two lights from the wall or screen, and the squares of these distances will give the ratio of illumination. Thus, if an Argand flame and a candle stand at the distances of ten feet, and four feet, respectively, when their shadows are equally deep, we have the square of ten, and the square of four, or one hundred,

and sixteen, as their relative quantities of light. In this experiment, the spectator should be equidistant from each shadow.

Light Houses.—Light houses are permanent beacons, erected along the seacoast, for the guidance of mariners in the night. Their general form is that of a small tower, with a lantern at top. Some of these have been erected, with great difficulty, on sunken reefs, or small rocks, exposed to the violence of the sea. Such is the case with the Eddystone, and Bell-rock light houses, on the coast of Great Britain, in the construction of which, much expense and great architectural skill were necessary, to insure their stability. Floating lights are sometimes used, to give notice of shoals. They consist of vessels, which are moored in the requisite situations, having lanterns fixed at their mast head.

Light houses were used by the ancients. The celebrated Pharos, of Alexandria, accounted one of the wonders of the world, appears to have existed as early as three hundred years before Christ. In England, they were in use, in the reign of Henry VIII., and in Scotland, in the time of James VI.

The lanterns, which form the top of light houses, are usually of an octagonal form, with windows for sides. The best are made of plate glass, with sashes of iron, or bronze. Within these are placed lamps, with Argand burners, the number and character of which are varied, so as to distinguish one light house from another.

The lights are either white or red, stationary or revolving, intermittent, flashing, double, or leading. Their intensity is increased by reflectors, placed behind them, which are generally of a parabolic form, made of copper, plated with silver, and highly polished; or, in cheaper constructions, made of tinned iron.

The *revolving* light is produced by the motion of a frame, carried by clock-work, having several faces, furnished with reflectors behind. As the frame revolves, the lights are observed gradually to increase, till they arrive at their greatest intensity, after which they gradually decline and disappear; and are succeeded by others in

the same manner. The *flashing* light is constructed on the revolving principle, but the revolutions being more rapid, and the light, in some cases, thrown through tubes, it is characterized by a succession of bright, transient flashes. The intermittent light is distinguished by its bursting suddenly on the view, and continuing steady for a short time, after which it is eclipsed for, perhaps, half a minute. This effect is produced by the periodical interposition of shades, by which the light is alternately hid and displayed. The *double* light consists of two lights, one above the other, displayed from the same tower. The *leading* lights are exhibited from two towers, one higher than the other, and, when seen in one line, they form a direction for the course of the shipping.

Gas Lights.—In the flame of a common lamp, or candle, the combustible matter is not burnt, until it has first been converted into vapor, or inflammable gás. This gaseous matter is burnt, as fast as it is generated, in consequence of being brought immediately in contact with the atmospheric air, and set on fire by the same heat which produces it. It is found, however, if certain combustibles be exposed to heat, and if the inflammable gas, which they yield, be kept separate from the atmospheric air, that this gas may be conveyed in pipes to any distance, and burnt for light in any place, where a stream of it is discharged into the atmosphere. In this way, various combustibles may be used, which are not capable of being burnt in lamps, and a brilliant and economical light obtained from them. The materials chiefly employed for this purpose, are *pitcoal*, and animal *oil*. Various other substances are capable of supporting gas lights, such as bitumen, resin, oleaginous vegetable seeds, other oily or resinous bodies, and even wood, and turf. The inflammable gas, which is procured from all these substances, is chiefly carburetted hydrogen. Of this, two kinds are known, the first, sometimes called olefiant gas, and the other, subcarburetted hydrogen. Mr. Brande, however, considers the last species as merely a mixture of the first with hydrogen. The fitness of a mixed gas, for purposes of illumination, is dependent on the quantity of carburetted hydrogen which it contains, other things being equal.

Coal Gas.—The use of coal gas, for purposes of illumination, appears to have been first introduced by Mr. Murdoch, in 1792, although its power of affording a luminous flame was known much earlier. It is found that the bituminous coals, and particularly cannel coal, afford the most, and the best, illuminating gas. Some of the anthracites, according to Professor Silliman, afford as much gas as Liverpool coal; but it burns with a feeble flame, and is unfit for the purposes of illumination.

In the manufacture of coal gas, the coal is placed in iron retorts, which are subjected to a strong heat in a furnace. The gas is thus driven off, mixed with the vapor of tar, oil, and ammoniacal water, and in this state is conducted by pipes, first into a horizontal trunk of cast-iron, called the hydraulic main, and from thence into a condensing apparatus, surrounded with cold water, where the vapors of the tar, oil, and water, are condensed, and fall down, while the gaseous product is conveyed along, containing several impure gases, such as sulphuretted hydrogen, and carbonic acid.

In order to separate the carburetted hydrogen from these impurities, various contrivances have been adopted. The usual method of purifying coal gas, is to make it pass through a mixture of lime and water, called *cream of lime*, which absorbs, or combines with, the contaminating gases. For this purpose, a considerable number of purifiers are erected, and the lime and water are kept in a state of constant agitation, either by a steam-engine, or by one or two men, till the gas is rendered sufficiently pure. Sometimes, the purification is effected, by causing the gas to pass in contact with solid lime, newly slaked; and, sometimes, by passing it through retorts, containing clippings of iron, made red hot. When thus purified, the gas is conveyed, by a pipe, to the gasometer.

The Gasometer, is a large inverted vessel, made of malleable iron, or copper, either of a cylindrical or rectangular form, and suspended over a reservoir of water, of a little larger size, by means of counter-weights. The gas is introduced by pipes, ascending from the bottom of the reservoir, and rising a little above the surface of the wa-

ter. While the gasometer is filling with gas, it gradually rises out of the water, until it is filled, after which no more gas is admitted, and its contents are ready to be distributed through the pipes, by which it is to be conveyed to the place intended to be illumined by burning it. As the gas is forced out by the weight of the gasometer, and is burned, the gasometer descends, gradually, in the water, till the whole of its contents are expelled, when it is again filled, by the same process as before.

The gas being thus ready for use, must be carried off by pipes, the diameter of which is proportional to the degree of light required. It has been found that a pipe one inch in diameter, will, under a pressure of a column of water from five eighths to three fourths of an inch, supply gas equal to one hundred candles; and if there was no friction, or mechanical impediment, the number of candles would be found, for other diameters of pipe, by multiplying the square of the diameter of the pipe, in inches, by one hundred. The friction, however, or obstruction, diminishes so rapidly with the diameter of the pipe, that the number of candles is always greater than this rule gives. Thus, a pipe three inches in diameter will supply light equal to one thousand candles; a pipe four inches, two thousand; a pipe six inches, five thousand; and a pipe ten inches, about fourteen thousand.

When the gas is to be burned in rooms, shops, or streets, it is allowed to escape through small circular apertures, of from one fortieth to one sixtieth of an inch in diameter, which may be arranged in various ornamental ways, or disposed in a circle, like an Argand burner, with a current of air running between them. The lights thus produced are equal, steady, and of the most brilliant kind. When the supply of gas is cut off, they are instantly extinguished. When it is restored, the invisible current flows out, and may be instantly lighted again by the contact of flame.

Oil Gas.—It has been long known to chemists, that wax, oil, tallow, &c., when passed through ignited tubes, are resolved into combustible gaseous matter, which burns with a bright light. Of late years, this gas has been used

for purposes of illumination. Oil gas is considered, in many respects, superior to coal gas, and free from its inconveniences. The material, from which it is produced, containing no sulphur, or other matter, by which coal gas is contaminated, it never produces a suffocating smell in rooms; so that the costly operation of purifying the gas, by lime, and other means, is avoided. Nothing is contained in oil gas, which can injure the metal, of which the conveyance pipes are made.

The oil gas has a further advantage over coal gas, in containing a greater proportion of carburetted hydrogen, so that one cubic foot of oil gas is said to go as far as two or three of coal gas. This circumstance is of importance, as it reduces, in the same proportion, the size of the gasometers, which are necessary to contain it. Oil gas contains about seventy-five per cent. of carburetted hydrogen, while purified coal gas but seldom contains more than forty per cent.

In procuring this gas, a quantity of oil is placed in an air-tight vessel, in such a manner, that it may pass slowly into retorts, or iron tubes, which are kept at a moderate red heat. Fragments of coke, or brick, are usually enclosed in the tubes. The oil, in its passage through the retorts, is principally decomposed, and converted into gas, proper for illumination, carrying with it, however, some oil, in the state of vapor. To purify the gas from this oil, which is suspended in it, and which occasions an empyreumatic smell, it is conveyed into wash vessels, where, by bubbling through water, or through fresh oil, it is cooled, and rendered fit for use. It then passes, by a proper pipe, into a gasometer, from which it is suffered to pass off in pipes, in the usual manner, to its places of destination.

The poorest kinds of oil, which are unfit for burning in lamps, produce excellent gas. This is, indeed, the chief source of economy in the process, which, otherwise, is too expensive.

According to Mr. Brande, a light, equal to ten wax candles, for one hour, requires for its production, two thousand and six hundred cubic inches of pure carburetted

hydrogen, or olefiant gas, four thousand eight hundred and seventy-five cubic inches of oil gas, or thirteen thousand one hundred and twenty cubic inches of coal gas.

Gasmeter.—In dispensing gas, for the illumination of particular rooms, it was found necessary to possess some method of measuring the quantity expended in each place. An ingenious instrument, called the gasmeter, has been introduced for this purpose. It consists of a horizontal cylinder, partly filled with water, within which, another cylinder revolves, on an axis, having its interior surface divided into several compartments. These compartments, being successively filled with the gas, as it passes through, rise out of water, like inverted buckets of an overshot wheel, and cause the inner cylinder to revolve. The number of revolutions is registered by machinery; and thus the quantity of gas which escapes, in a given time, is estimated.

Portable Gas Lights.—The magnitude and expense of gas works prevents the use of them, except in cases where a large number of lights are wanted, within a convenient distance from the gasometer. The gas, however, may be conveyed to any distance, by condensing it in strong vessels of iron or copper, made of a small or portable size. The gas is forced into these vessels by a condensing pump, and, when afterwards suffered to escape, through a small orifice, is capable of supporting a flame for many hours. The economy, however, of this process has, with reason, been doubted.

Safety Lamp.—In coal mines, an inflammable gas is generated, called *fire damp* by the miners, and composed chiefly of carburetted hydrogen. This gas, when mixed with atmospheric air, is liable to take fire from the flame of a lamp, or candle, and to explode with great violence. Terrible accidents have happened, and many lives have been destroyed, from these explosions. To prevent such accidents, several troublesome and circuitous modes of obtaining light were resorted to by the miners; such as striking sparks from a wheel, and enclosing a lamp within a tight lantern, which was supplied with air from a bellows. All these are now superseded by the *safety lamp* of Sir Humphrey Davy. This important invention con-

sists simply of a lamp, the flame of which is wholly enclosed in a cylinder of fine wire gauze. Its operation depends on the principle discovered by Sir H. Davy, that explosive mixtures cannot be inflamed through minute apertures, in metallic surfaces, or tissues. The wire gauze, being a powerful conductor and radiator of heat, cools a flame which is in contact with it, so as to deprive it of the power of producing an explosion on the other side. If this lamp be immersed in an explosive mixture, the gas will be inflamed, and burn on the inside of the gauze cylinder, but not on the outside. In these cases, the flame of the lamp first enlarges, and is then extinguished, the whole of the cage being filled with a lambent blue light. If the supply of gas be withdrawn, this appearance gradually ceases, and the wick becomes rekindled.

Recently, it has been found, that the Davy lamp is not a protection against explosion, when exposed to much motion, or to a current of air. It has, therefore, been improved by Messrs. Upton and Roberts, so as to keep, between the flame and the external air, a layer of carbonic acid, a cylinder of wire gauze, and a cylinder of glass.

Lamp without Flame.—This curious instrument may be made, by winding upon the wick of a lamp, containing alcohol, a fine wire of platinum, not more than a hundredth part of an inch in thickness. There should be about sixteen spiral turns, one half of which should surround the wick, and the other half rise above it. Having lighted the lamp for an instant, on blowing it out, the wire will become brightly ignited, and will continue to glow, as long as any alcohol remains, without the blaze being any more renewed. The principle depends upon the slow combustion which is found to take place, in inflammable or explosive mixtures, at a lower temperature than is necessary to produce inflammation. This combustion is not visible; but the heat is, nevertheless, sufficient to ignite minute solids, exposed to its influence. In the lamp, which has been described, the explosive mixture is the vapor of alcohol and atmospheric air. But the experiment may be varied, by using ether, camphor, &c., and by substituting platinum leaf, for wire.

Modes of procuring Light.—To obtain light and fire, when wanted, in an expeditious manner, various instruments have been introduced, constructed on optical, mechanical, and chemical, principles. The methods, by which they operate, are, chiefly, the following. 1. By concentration of the solar rays, as in the focus of a common lens, or burning glass. 2. By friction. Dry wood takes fire, if rubbed violently, in the manner practised by savages, or if it be held against the surface of a wheel which revolves rapidly. Phosphorus takes fire by very slight friction, and, on this account, is used in the *phosphoric fire bottles*, the matches of which, after being charged with a minute quantity of phosphorus, take fire by rubbing them on the cork. Other matches, now very common, have their ends coated with a mixture of phosphorus and sulphur. 3. By percussion. When hard bodies, such as flint and steel, are brought into collision, small particles of ignited matter are struck off, in the form of sparks, which are sufficiently hot to set fire to tinder, gunpowder, &c. Common firelocks, tinder-boxes, &c., operate on this principle. 4. By compression. If a piece of tinder is confined in a small cavity, at the end of a condensing syringe, it will take fire, if the piston of the syringe be driven down with a stroke, so as suddenly to condense the air. The tinder, commonly used for this purpose, is what is called German tinder, made of a fungus that grows on trees, (*Boletus igniarius*,) boiled in a solution of nitre, and dried. 5. By chemical action. In the *oxymuriatic fire boxes*, the matches are charged with chlorate of potash, mixed with sulphur, or some other combustible. When these are brought into contact with sulphuric acid, a violent chemical action takes place, and the match takes fire. Homberg's *pyrophorus* takes fire, on exposure to the air. It may be made by calcining alum with less than an equal quantity of flour, or sugar, until the smoke and flame disappear. It is then kept in close-stopped bottles ; and, if a little of it be shaken out, upon any light combustible, as cotton or tow, it causes it to inflame. The *platinum lights* depend on a remarkable property, discovered by

Dobereiner, in platinum, by which a sponge, made of that metal, becomes ignited, when exposed to a stream of hydrogen gas.

Works of Reference.—Accum, on Gas Light, 8vo. 1816;—Peckston, on Gas Lighting;—Rumford's Works;—Nicholson's Philosophical Journal, vol. i. 4to. vol. xiv. 8vo., &c.—Rees' Cyclopedia;—Ure's Chemical Dictionary;—Ditto, Dictionary of Arts and Manufactures, 8vo. 1839.

GLOSSARY.

Many words, not contained in this Glossary, will be found defined, or described in the body of the Work, in their proper places. For these, see *Index*.

Acanthus, a plant, growing in Greece and Italy.
Acescent, becoming sour.
Acetous, having the character of vinegar.
Acicular, shaped like needles.
Acid, a substance, or fluid, which turns vegetable blues to a red, and forms saline compounds with alkalies. Most of the acids contain oxygen.
Acropolis, the summit of a city, a citadel.
Affinity, the attraction between the particles of bodies, which causes them to enter into chemical combination.
Albumen, a substance found in living bodies, which coagulates by heat. White of egg is an example.
Alburnum, the soft or sap wood of trees, outside of the heart.
Alcohol, an inflammable liquid, which is the basis of ardent spirits.
Alhambra, a celebrated structure, built by the Moors at Granada, in Spain.
Alkali, a substance in chemistry, which turns vegetable blues to a green, and combines with acids, forming salts.
Alumine, an earth, which exists in clay, alum, &c.
Ammonia, volatile alkali.
Angle of incidence, the angle at which a ray falls on a reflecting surface.
Apollo de Belvidere, a celebrated antique statue, now in the Vatican at Rome.
A priori, from previous causes.
Aqueous, made with water.
Arc, part of a circle, or other curve.
Argillaceous, containing clay, or resembling it.
Argillaceous schist, common slate.
Atoms, or *atomic weights*, the original quantities, in which the different objects of chemistry combine with each other, considered in reference to another body.
Atrium, the principal hall in a Roman house. See page 62.
Augustan age, the time of the Roman Emperor Augustus.
Autograph, the original handwriting of a person.
Basalt, a rock, which is often found in regular blocks, forming columns, as in the Giant's Causeway, in Ireland.
Basilica, an ancient hall of justice.

Beau ideal, ideal beauty. Beauty surpassing what exists in Nature.
Bichloride, a double chloride. A compound, having two proportionals of chlorine.
Biliary concretions, lumps, which collect in the gall bladder, &c., of animals.
Bitartrate, any salt which has two proportionals of tartaric acid.
Borax, a salt, composed of boracic acid and soda.
Breccia, a kind of marble, composed of angular fragments, imbedded in a cement of a different color.
Cæcum, a part of the intestine.
Cæteris paribus, other things being equal.
Calcareous, consisting, chiefly, of lime.
Calcined, reduced, or altered, by heat, but not melted.
Camera lucida, *Camera obscura*, optical instruments, by which the images of things are thrown upon a paper, or other plane surface.
Cameræ vitreæ, glass chambers.
Campus Martius, the Field of Mars, or training-field of the Romans.
Caoutchouc, India rubber. See page 112.
Capillary attraction, the force by which fluids are drawn into minute cavities, or tubes; as oil in the wick of a lamp.
Carbonaceous, containing carbon or coal.
Carbon, a simple inflammable body, forming the principal part of wood and coal, and the whole of the diamond.
Carbonate, a compound or a salt, containing carbonic acid.
Carbonic acid, a compound gas, consisting of carbon and oxygen. It has lately been obtained in a solid form.
Carbonization, conversion into coal.
Carburetted hydrogen, a gas, composed of carbon and hydrogen; as coal gas.
Catacombs, tombs of large size, capable of containing many bodies.
Cellular, composed of little cells, or cavities.
Centaur, a fabulous animal, half man and half horse.
Centrifugal, tending away from the centre.
Chemical rays, rays of light, which occasion chemical changes in certain bodies.
Chloride, a compound of chlorine and some other substance.
Chlorine, a simple substance, formerly called oxymuriatic acid. In its pure state, it is a gas, and, like oxygen, supports the combustion of some inflammable substances.
Choragic, the name given to certain Grecian games, and to monuments erected in honor of those who conquered or excelled, in these games.
Chromate, a combination of chromic acid.
Chronometer, a watch, or time-keeper, of great accuracy, used in determining longitude.
Clepsydra, a water-clock.
Cloacæ, large drains, constructed under ground by the Romans.
Coliseum, or *Colosseum*, a large ancient amphitheatre, erected by the Emperor Vespasian, now standing at Rome.
Colossal, larger than life. Thus, a statue eight or ten feet high, is Colossal.
Comminuted, broken into fine fragments.
Concavo-convex, concave on one side, and convex on the other.

Conchoidal, rounded, like a shell.
Concrete juice, a juice which has become solid by drying.
Conic sections, the curves produced by cutting across a cone, in different directions.
Copal, a resin, used for varnishes.
Copperas, sulphate of iron.
Corrosive sublimate, a poisonous substance, called, in chemistry, bichloride of mercury.
Corundum, a very hard, crystallized stone, found in India and China.
Crystallization, the process of forming crystals.
Crystals. This name is given to the geometrical forms assumed by many bodies, especially salts and minerals.
Cuticle, the outer skin of a plant or animal.
Cyclopean walls, walls found in certain parts of Greece, which, from the great size of their stones, were fabled to have been constructed by ancient Cyclops, or giants.
Decoction, water in which part of a substance has been dissolved, by boiling.
Decompose, to separate the chemical constituents of a compound body.
Desideratum, a thing wanted, but not yet discovered.
Deoxidize, to deprive a substance of its oxygen.
Dextrine, a gummy matter, derived from starch. Its effects in the polarization of light will be found in the appropriate works.
Disc, a circular surface, which appears plane, or is so.
Druids, ancient priests of Britain.
Ductile, capable of being extended by drawing out, as in wire-making.
Eccentric, or *excentric wheel*, a wheel, the axle of which is not in the centre.
Empyreumatic, having a quality as if burnt.
Equilibrium, a state of rest, produced by the equal balancing of weight, pressure, or other forces.
Ether, a light, volatile liquid, prepared from alcohol and some acid.
Exfodiations, diggings, or excavations in the earth.
Extract, the juices of a plant, made solid, or partly so, by drying.
Facade, the front, or face, of a building.
Fac simile, an exact imitation, in writing, &c.
Fahrenheit, the inventor of the thermometer which is most used in this country.
Fecula, a vegetable principle, which forms the basis of flour and starch.
Feldspar, a hard kind of stone, found in granite. See page 84.
Ferrocyanite, a compound of the ferrocyanic acid with some base.
Filter, to strain through paper.
Fluate of lime, or *Fluor spar*, lime combined with fluoric acid. At Derbyshire, in England, it is found in crystalline masses, beautifully variegated with purple.
Forum, a public square at Rome, in which meetings of the people were held.
Fossils, substances found under ground.
Friable, easily reduced to powder.
Frustum, the lower part of a cone or pyramid, &c., cut off by a plane.

Fugacious, fading, or vanishing.
Fugitive color, fading, transitory.
Gas, a name applied to the different species of air, as oxygen gas, coal gas, &c.
Gasometer, a vessel inverted in water, or other fluid, for the purpose of containing gases.
Galvanic, *Galvanism*, the kind of electricity which is developed by the combination of metals.
Gauls, the ancient inhabitants of Gaul, or France.
Ghizeh, a place on the banks of the Nile, near Cairo, celebrated for its pyramids.
Glaze, a transparent coating, or covering.
Gypsum, plaster of Paris, a kind of earth, consisting of sulphate of lime.
Hexagonal, six-sided.
Hieroglyphics, ancient letters, or characters, used, chiefly, by the Egyptians. Some of them were in the form of animals, instruments, &c.
Hydrate, a solid compound with water.
Hydrate of lime, a compound of lime with water.
Hydraulics, the science which treats of the motion of fluids.
Hydrochloric acid, see *Muriatic Acid*.
Hydrogen, a very light, inflammable gas, of which water is, in part, composed. It is used to inflate balloons.
Hydrostatics, the science which treats of the pressure of fluids.
Hydrosulphuret, a compound of hydrogen and sulphur with another body.
Ignited, heated red hot, or white hot.
Impluvium, part of a Roman house. See page 62.
Incidence. See *Angle of incidence*.
Infusion, a solution of a vegetable substance, made without boiling.
Inspissated, thickened, as when the juice of a plant is partly dried.
Iodine, a simple substance of a grayish, black color, and metallic lustre, having a violet-colored vapor. It is obtained from marine plants.
Isinglass. This name is applied to a mineral substance, (see *Mica*, page 86,) and also, to a kind of glue, or gelatin, procured from the swimming-bladders of certain fishes.
Labyrinth, an intricate building or passage, from which it was difficult to find the way out.
Lackers, or *lacquers*, varnishes for metals.
Lachrymatories, small urns, found in the tombs of the Greeks and Romans; so named, from their being supposed to contain the tears of the relatives of the deceased.
Lapidary, a workman in precious stones.
Lapis Albanus, a stone from Alba.
Lava, the melted substances ejected from volcanos.
Lentil, a kind of seed.
Levigated, rubbed into fine powder on a stone.
Ley, water which has percolated through ashes, earth, or other substances, dissolving and containing a part of their contents.
Lias, a fine-grained limestone used in lithography.

Lichen, a kind of moss, common on rocks, barks of trees, &c., of of which there are many kinds.
Lime water, water in which lime is dissolved.
Litharge, an oxide of lead partly vitrified, or converted into glass.
Litre, a French measure, somewhat exceeding a quart.
Lozenge, a four-sided figure, like a rhomb, or a diamond on cards.
Louvre, a large building in Paris, containing pictures, and other works of art.
Magnesia, a kind of earth, light and white, with alkaline properties.
Maison Carrée, "square house."
Malleable, capable of being spread out by hammering.
Manipulations, operations by hand.
Metre, a French measure, somewhat exceeding a yard.
Mica, isinglass. See pages 84 and 86.
Microscope, an optical instrument, which increases the apparent magnitude of objects.
Microscopic, too small to be seen, without a microscope.
Minerva, the ancient goddess of wisdom.
Minotaur, a fabulous monster, said to be half man and half bull.
Monolith, *Monolithic*, made of one stone. Thus, a monolithic column or statue consists of a single piece.
Mordant, a substance used in dyeing, to fix colors upon cloth.
Mummies, bodies of the dead, preserved by embalming and drying.
Muriatic acid, an acid, composed of chlorine and hydrogen, called, also, hydrochloric acid, and spirit of salt.
Naphtha, a kind of mineral tar.
Native, as found in Nature.
Nitre, or *saltpetre*, a salt, used in making gunpowder, &c. Nitrate of potass.
Nitric acid, an acid composed of oxygen and nitrogen.
Nitrogen, or *azote*, a simple substance, which exists, in the form of gas, in the atmosphere. It does not support respiration nor flame.
Nucleus, (plural *Nuclei*,) a centre. A kernel of a fruit.
Octagonal, eight-sided.
Oxidable, capable of being oxidized.
Oxidation, combination with oxygen ; as in the rusting and tarnishing of metals.
Oxide, a compound (which is not acid) of a substance with oxygen :— Example, oxide of iron.
Oxygen, a simple and very important substance, which exists in the atmosphere, and supports the breathing of animals and the burning of combustibles.
Oxymuriatic acid. See *Chlorine*.
Pagoda, a Chinese tower.
Papyrus, a reed, of which the ancients made paper.
Parabolic, having the curved form of a parabola.
Parthenon, the temple of Minerva, at Athens.
Percolate, to trickle, or strain, through a porous body, as water passes through sand or ashes.
Peritoneum, the fine membrane which covers the intestines of animals.
Persepolis, an ancient city in Persia.

Pharos, a high tower. A lighthouse.
Photography. This word, by its etymology, means writing or engraving, by light.
Photometry, the measurement of light.
Physics, natural philosophy.
Piazza del Popolo, a square in modern Rome.
Pigments, coloring substances, used in painting.
Porcelain, fine earthen, or Chinaware.
Potassa, an alkali, composed of potassium and oxygen.
Potassium, a light and very inflammable metal, discovered in potass, by Sir H. Davy.
Propylon, or *Propylæon*, (plural *Propylæa*,) a large portico.
Proscenium, part of a theatre. See page 277.
Proto-sulphate, a compound of one proportional of sulphuric acid with a base.
Pyrites a metal, combined with sulphur, often in a crystalline form.
Pyroligneous acid, an acid, obtained from the smoke of wood.
Pyrometer, an instrument for measuring high degrees of heat, as in furnaces, &c.
Pumice stone, a very light, porous, gritty stone, of volcanic origin, used in polishing and grinding.
Puzzolana, see page 92.
Quartz, rock crystal. See page 84.
Quicklime, burnt limestone.
Reaumur, the inventor of a thermometer formerly used in France.
Refractory, difficult to fuse, or melt, in a furnace.
Relief, } a mode of carving raised figures on a surface, like the head
Relievo, } on a coin.
Repeating-watch, a watch which strikes the hour when a spring is pressed.
Residuum, the part which remains.
Resins, a kind of vegetable products, which are inflammable, and dissolve in spirit, but not in water.
Resinous, of the nature of resin, or rosin.
Retina, the part situated in the back of the eye, which is sensible to light.
Rhus copallinum, a species of sumach.
Sacristy, the part of a church in which the consecrated vessels, holy relics, &c., are kept.
Saracens, ancestors of the present Turks and Moors.
Saltpetre, see *Nitre*.
Sarcophagus, a stone coffin. Of these, there were many shapes.
Sardonyx, a kind of precious stone.
Savans, the French term for scientific men.
Scarabæi, beetles, insects held sacred by the Egyptians.
Scoria, slags. The refuse of furnaces, &c., after melting.
Segment, a part cut off by a plane.
Silex, an earth, of which glass is made. It exists in flints, sand, &c.
Silicious, containing silex, or flint.
Sistrum, an ancient musical instrument.
Size, glue, or gelatin, dissolved in water.
Solution, a liquid, having a substance dissolved in it.

Solvent, a fluid, capable of dissolving.
Souterrain, a place under ground.
Spatula, an instrument, with a broad blade, used for spreading.
Specific gravity, the weight of a body, as compared with that of water.
Spectrum, an image of seven different colors, produced by the rays of light passing through a prism.
Spheroid, a body, resembling a sphere in shape, but either longer, or more flat.
Sphinx, a fabulous animal, having the body of a lion and the head of a woman. The andro-sphinx had the head of a man.
Stadium, (plural *stadia*,) a Greek and Roman measure. A furlong. Also, a race-course.
Sublimation. In chemistry, a substance is said to be sublimed, when it passes, by heat, from a solid form to that of gas, without melting.
Subtend, to reach across, between two lines which make an angle.
Sulphur, or *brimstone*, a simple, inflammable substance, well known.
Sulphuret, a compound of sulphur with another body.
Sulphuretted hydrogen, a gas, composed of sulphur and hydrogen.
Sulphuric acid, an acid composed of oxygen and sulphur.
Suspended, floating, or mixed, but not dissolved.
Syphon, a crooked tube, in which water running down the longer half will cause water to run up the shorter half, by atmospheric pressure.
Tamarisk, a tree, growing in countries about the Mediterranean.
Tambours, or *frusta*, the round blocks of which columns are made up.
Tannin, a substance, found in the oak, and other trees and plants; used in tanning hides.
Tanno-gallate, a combination of tannin and gallic acid with another substance.
Tartar, a substance, deposited on the inside of wine casks, consisting chiefly of tartaric acid and potass.
Terra cotta, baked earth, or burnt clay.
Thermæ, baths of the Romans, which were large and magnificent buildings.
Thermometer, an instrument, for measuring heat.
Trapezoid, an irregular figure of four sides, no two of which are parallel.
Unguent, ointment.
Vatican, a palace at Rome, the Winter residence of the Pope. It is celebrated for its vast collection of works of art. It contains upwards of four thousand rooms, many of which are filled with rare and costly paintings, statues, an immense library, &c.
Veneering, the art of covering wood with a thin layer of wood of a different kind.
Venus de Medicis, a celebrated antique statue of great beauty, now at Florence.
Verdigris, an acetate of copper, used as a paint.
Vestibulum, the threshold of a house. See page 62.
Villa, a country seat, or residence.
Vinous, having the character of wine.
Volatile oils, oils which evaporate by moderate heat.

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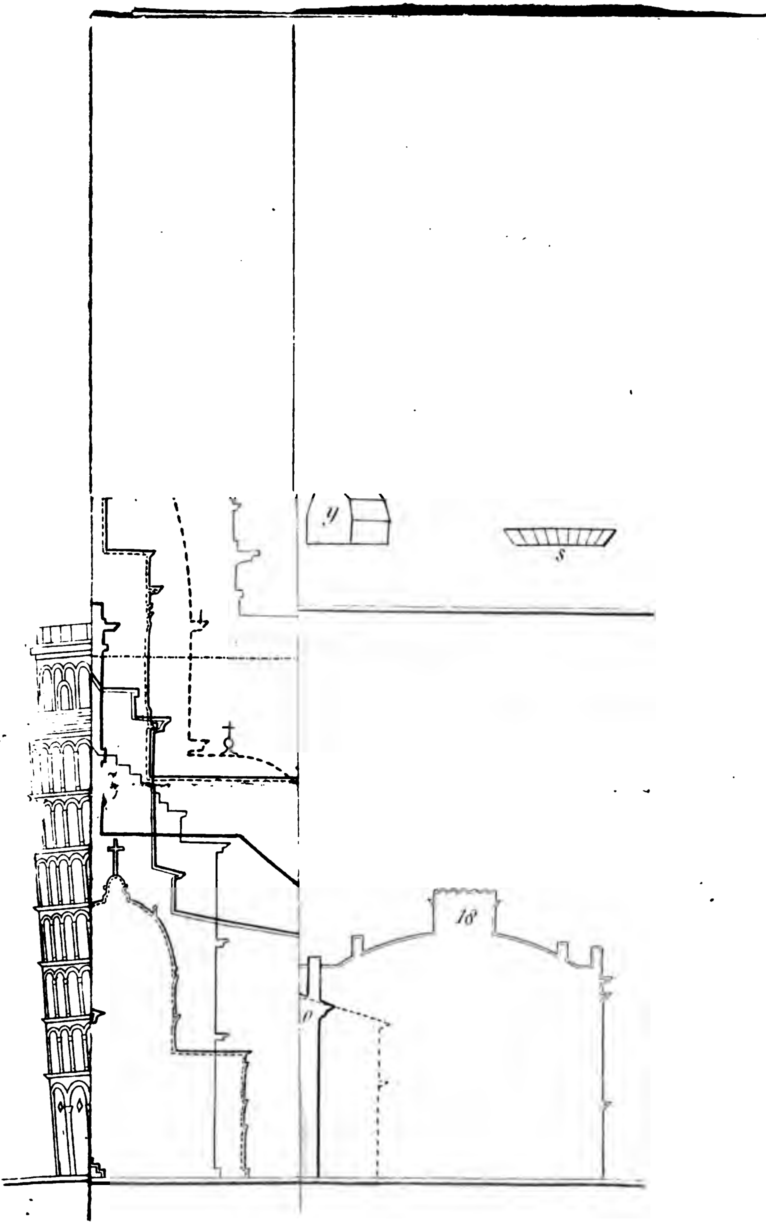
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SCIENCE AND THE ARTS, by the Rev. ALONZO POTTER, D. D., *Professor of Moral Philosophy and Rhetoric, in Union College, Schenectady, N. Y.*

The design of this Work is to call attention to the fact that the Arts are the result of *intelligence*—that they have, each one its *principles* or *theory*—that these principles are furnished by *Science*, and that he, therefore, who would understand the Arts, must know something of Science; while, on the other hand, he who would see the true power and worth of Science ought to study it in its applications. The work will be made up of *facts*, illustrating and enforcing these views—so arranged as to exhibit the invariable connexion between *processes* in *Art*, and *laws* in *Nature*. The importance of such a work requires no comment.

AGRICULTURE, by the Hon. JUDGE BUEL, of Albany, *Editor of 'the Cultivator.'*

This Work is intended as an aid to the *Young Farmer*, and from the known character of the gentleman who has it in hand, there can be no doubt but that it will be executed in a highly satisfactory manner. The following, among other subjects, will be therein treated of, viz.

1. The Importance of Agriculture to a Nation.
2. Improvement in our Agriculture practicable and necessary.
3. Some of the principles of the new and improved Husbandry.
4. Agriculture considered as an Employment.
5. Earths and Soils.
6. Improvement of the Soil.
7. Analogy between Animal and Vegetable Nutrition.
8. Further Improvement of the Soil.
9. " " by Manures, Animal and Vegetable.
10. " " by Mineral Manures.
11. Principles and Operations of Draining.
12. Principles of Tillage.
13 Operations of Tillage, &c. &c.

Due notice will also be taken of alternating crops, root husbandry, mixed husbandry, the management of pasture and meadow lands, the garden, orchard, &c.

Cuts, illustrative of the various operations spoken of and recommended, will be given.

GEOLOGY AND MINERALOGY, by CHARLES T. JACKSON, M. D., *Geological Surveyor of Maine and Rhode Island.*

STATISTICS OF THE UNITED STATES, by GEORGE TUCKER, *Professor of Moral Philosophy in the University of Virginia, Author of 'the Life of Jefferson,' &c. &c.*

AMERICAN TREES AND PLANTS, used for medicinal and economical purposes and employed in the Arts, with numerous engravings ; by Professor JACOB BIGELOW, *Author of 'Plants of Boston,' 'Medical Botany,' &c. &c.*

MORAL EFFECTS OF INTERNAL IMPROVEMENTS, by ROBERT RANTOUL, Jr., Esq.

LIVES OF THE REFORMERS, by Rev. ROMEO ELTON, *Professor of Languages in Brown University.*

BIOGRAPHICAL SKETCHES OF DISTINGUISHED FEMALES, by Mrs. EMMA C. EMBURY, of *Brooklyn, N. Y.*

SKETCHES OF AMERICAN CHARACTER, by Mrs. SARAH J. HALE, *Editor of 'the Ladies' Book,' Author of the 'Ladies' Wreath,' 'Flora's Interpreter,' &c. &c.*

DO RIGHT AND HAVE RIGHT, by Mrs. ALMIRA H. LINCOLN PHELPS, *Principal of the Literary Department of the Young Ladies' Seminary, at West Chester, Pa., formerly of the Troy Seminary, N. Y., Author of 'Familiar Lectures on Botany,' 'Female Student,' &c.*

The object of this Work may be gathered from the following remarks of Mrs. Phelps. "A popular work on the principles of law, with stories illustrating these principles, might be very profitable to people in common life, as well as to children. The ward cheated by a guardian, the *widow* imposed on by administrators or executors, the *wife* abandoned by a husband, with whom she had trusted her paternal inheritance, the *partner* in business, overreached by his crafty associate, for want of a knowledge of the operations of the law,—all these might be exhibited in such a way as to teach the necessity of legal knowledge to both sexes, and to all ages and classes."

SCENES IN THE LIFE OF JOANNA OF SICILY, by Mrs. E. F. ELLET, *of Columbia, S. C.*

This is written with a view to young readers, and for the purpose of illustrating important historical events.

The Publishers have also in preparation for this Series, a History of the United States, and of other Countries, a History of the Aborigines of our Country, a History of Inventions, Works on Botany, Natural History, &c. &c. Many distinguished writers, not here mentioned, have been engaged, whose names will be in due time announced, although at present, we do not feel at liberty to make them public.